

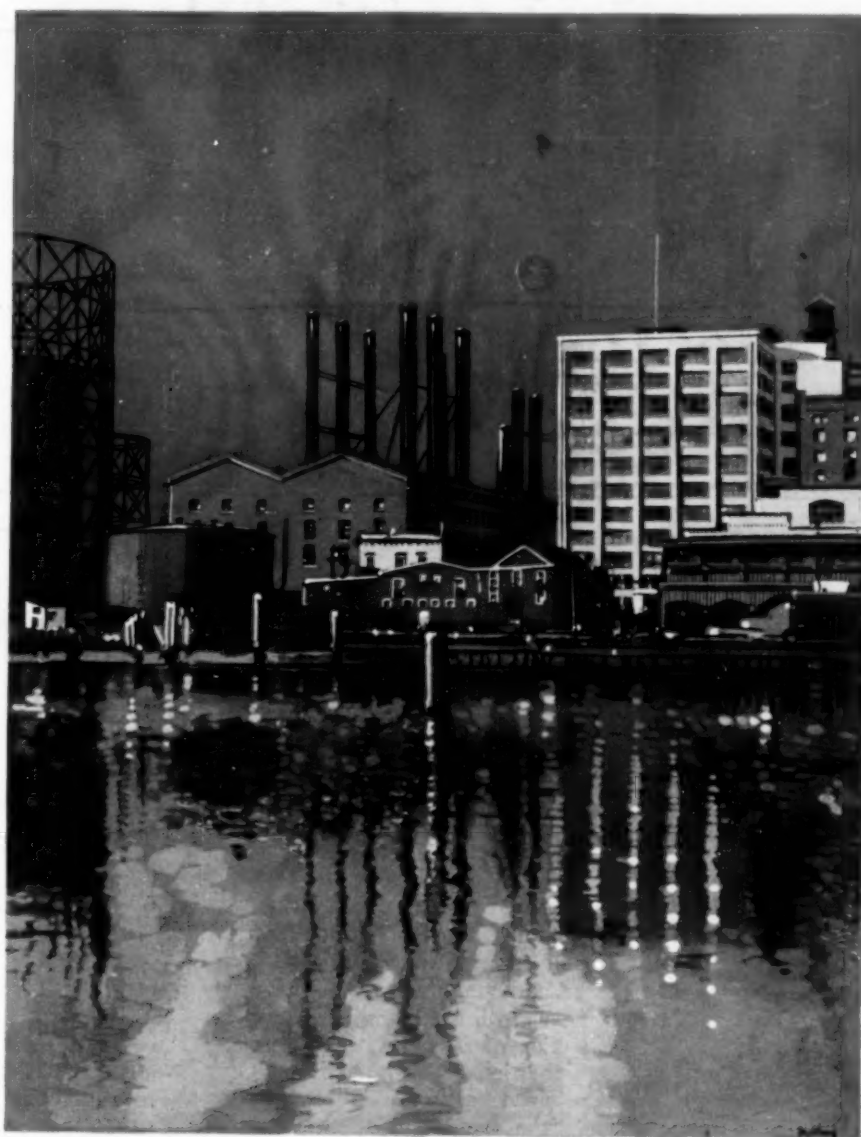
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CHEMICAL & METALLURGICAL ENGINEERING

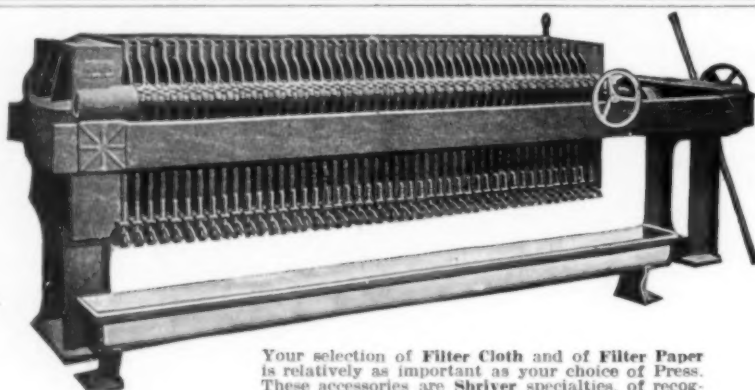
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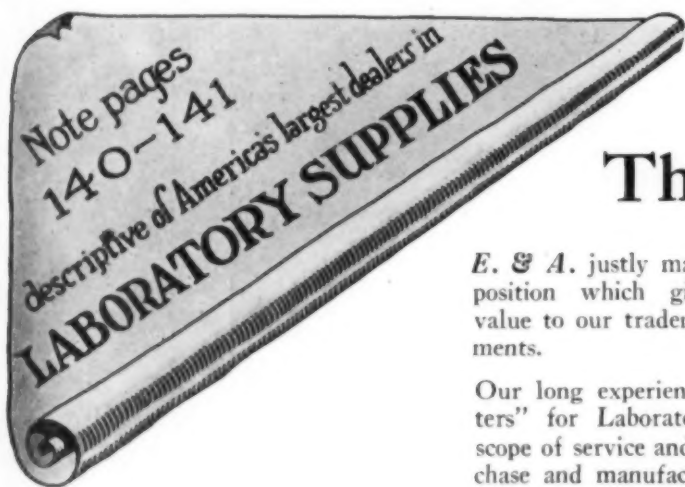
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CHEMICAL & METALLURGICAL ENGINEERING

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H. C. PARMELEE, Editor

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Number 11

A New Fraternity— The Chemical Engineering Industries

"DEDICATED to the brotherhood of man." This impressive message is inscribed on the main arch of the great Jewish Temple in Boston. It seems altogether appropriate that so magnificent a monument should, in its dedication, proclaim an ideal, forever after to stand as a challenge and an appeal to everyone who runs and reads to do his part in reaching and maintaining that ideal.

It is no less appropriate to dedicate any worthy achievement to a brotherhood of interest in a great community of mankind, whether it be of religion, of clan, of nation, of profession or of avocation. Therefore, we of "Chem. & Met.," in the just pride of a task well accomplished and with due acknowledgment to our contributors, dedicate this symposium on unit processes to the men of the chemical engineering industries.

The symposium itself is the prototype of a service that we

pledge to continue, a service that deals with a fundamental branch of technology—the technology of unit processes. Although the industries have been using these same processes for years and in many cases centuries, it has been only recently that their technology has become a branch of engineering. It is still more recently that the consciousness of identity of problems, identity of equipment, identity of operating method has begun to knit these great industries together.

The production men of these industries, be they engineers or chemists, college men or those who have grown up in the plant, are awakening to the realization that their industries are built up of these unit processes of chemical engineering.

It is to this awakened consciousness, to the new brotherhood based on the practice of a fundamental technology, that we dedicate our energy and our strength.



The Plan of This Issue

AS YOU open this special number of *Chem. & Met.* you will discover that it contains a symposium on our now familiar theme: "Chemical Engineering in Industry." In this symposium there are fourteen chapters, each discussing one of the unit processes of chemical engineering. Obviously this does not complete the list of unit processes. It does not include, on the one hand, the mechanical engineering of transporting solids, liquids and gases, the material-handling functions that link other unit processes together, or the mechanical engineering of the application of heat. Nor, on the other hand, does it deal with the various types of chemical reactions that may readily be classed in rough groups such as solid, liquid and gaseous phase reactions, catalyzed reactions, roasting and calcining, reactions under pressure, and fermentation reactions.

The unit processes described in this issue divide themselves into three groups. The first contains the two processes that have to do with the mechanical conditioning of matter, disintegration (crushing, grinding and pulverizing) and integration (mixing, kneading and agitation). Group two contains the processes dealing with the mechanical separation of one substance from another without any change in phase or physical state of the material. For example, there is the separation of solids from liquids by screening, flotation or air; of solids from liquids by thickening, filtering or centrifuging; of solids from gases by electricity or filtration.

The third group again deals with the separation of one material from another, but the separation is accomplished by changing the phase of one constituent. For example, in drying a substance the water is removed by vaporizing it and in evaporation a liquid is also removed by vaporization.

These groups might be called the applied physics of chemical engineering, as there is seldom involved in any of the processes a chemical change in material. They form, however, the main structure of the chemical engineering industries, and it is on this firm foundation that progress must be built.

That Most Practical Man— The Theorist

ALL of the fundamental processes of chemical engineering described in this issue are concerned with two things—force and matter. It falls to the lot of the chemical engineer to apply these forces in the segregation or aggregation of chemical particles. It stands to reason, therefore, that in this work the more we know of the structure of these particles the better we shall be able to accomplish what we set out to do.

To illustrate this need of greater and more comprehensive knowledge of the nature of the different kinds of matter, let us imagine a problem of chemistry in the large, with particles so big that we can both see and hear them. Let us imagine ourselves as within a house or great shack (with everything, including ourselves, as primeval), the dwelling set in a wide inclosure and within the inclosure a large number of animals that keep up such a racket with their fighting that we cannot rest. Our problem is to obtain greater quiet. To ac-

complish this we begin by the empirical method of throwing stones at the animals, which is not effective. In doing so we pursue research according to the method of trial and error, with negative results. After many other experiments we try throwing meat at them, and finally we discover that if we throw it continuously and in sufficient quantity, the animals feed to repletion, grow fat and lazy and become more quiet. The method then becomes traditional and refinements are developed. Men of wealth and influence sit complacently on the boards of directors of meat-throwing organizations which charge high prices for the services of their expert meat-throwers.

Finally somebody really practical comes along. The fact is not recognized by the meat-throwers and the boards of directors who represent investments in the art. They call him a theorist, and even wax profane whenever they discuss his work. He makes a study of the animals that make the noise. He discovers that they are dogs and cats. This discovery is declared to be vapid theorizing. He observes that dogs and cats do not live together in harmony, which is more theorizing, according to the popular notion. He discovers that cats can climb trees, which dogs cannot, and that cats will follow a catnip trail, which dogs will not. Study of this sort becomes the butt of ridicule and as humorous as the positive lack of bananas. But when the man of research builds a runway from the upper branches of the tree to a hill beyond the inclosure and baits it with catnip, the cats all go away, which leaves us in the comparative quiet of dogs without cats. Then we build a monument to the inventor, after he is dead, and we tell our children how thankless people were, in the benighted past, to those who brought them the greatest blessings.

Now in the unit processes under consideration, we have much to do with gases and liquids and solids and we are almost constantly engaged in dealing with that ubiquitous substance known as water. Consider some of the things we do not know about it. What is the conformation of its molecule? Given its shape, which we do not know, where are its several fields of force? How do they act? Why does it climb a tree? Just giving a name to the fact that it climbs through capillaries does not tell why it does so. What is it within or on the molecule that corresponds to the cat's claws? Granted that the vapor is H_2O , the liquid $(H_2O)_2$ and the solid $(H_2O)_x$, how are the molecules organized? Why does it expand as it hardens? We don't want a guess, we want an answer computed from its molecular fields of force. Why does it form hydrates? If ice is $(H_2O)_x$, why is it that so many solid hydrates are $X \cdot 10H_2O$?

This same substance turns up and fairly laughs at us every time we produce a salt. What is its relation to acids and bases, or rather, what is an acid and what is a base? We have never found a satisfactory answer yet in the literature and J. W. Mellor, who is one of the best of all expositors of chemistry, has given it up as a bad job. The key to the riddle lies somewhere in that pesky H_2O .

The kinetic molecular hypothesis gives us just a little hint of the behavior of molecules in the liquid phase, but this is nothing like as clear as our sense of their behavior in a gas. In the latter we have a picture of molecules floating about like balloons, banging into one another and bobbing about. But until we know their



conformations and their fields of force, we can hardly hope for so clear a vision of a liquid.

This need is a call for the man of pure science, and for his contribution of the vision of things unseen. Experience and practice alone will not bring it. The understanding that is still lacking in regard to so many things is not picked up by accident or discovered by a lucky strike. It will come only as a result of long, earnest, almost passionate seeking by those who are equipped with great scholarship.

The drive to seek and find fundamental things is rare. Most of us want to make things to sell. We lack the super-curiosity and the patience to spend our lives in the fields of the unknown and to seek knowledge rather than rewards. These supremely practical men who are often referred to as theorists are the very foundation of our hope for better knowledge, greater understanding and improved technology.

Experience,

The Good Teacher

CHEMICAL engineering as a science or profession is so new that its definition is still in the making; yet it is so old that many of its basic processes date from the very beginnings of industry. It is a structure resting on a foundation of empirical knowledge accumulated during centuries of experiment and practice. In recent years the application of theoretical science has been largely responsible for the rapid growth of the superstructure, but underlying this is the stable groundwork of experience—the importance of which many chemical engineers of the present generation are prone to underestimate.

The empirical philosophy of the ancients taught that "experience is the source of all knowledge." The process of trial and error, the coincidence of many observations, determined the course of the empiricist. Reasoning independent of experience was heresy. And yet it was in such an age that most of the unit processes of chemical engineering had their inception and early development. It is difficult to trace the antiquity of many of these methods as we know them today, but certainly some of them are as old as civilization itself. Concentration of sea water by solar evaporation or over the open fire, followed by the crystallization of the salt, came early in man's history. Crushing and grinding of powders and medicines and the mixing of ores and fluxes were practiced by the early Egyptians. Drying is even more ancient. Distillation dates from the days of the Arabian physician, whose *alembic* may be regarded among the forerunners of modern chemical engineering equipment.

Georg Agricola (1490-1555) was perhaps the first chemical engineer—if by that we mean the first to develop industry by the application of the principles of chemical science—yet even in his time our chemical engineering processes were in service in industry. The salt and sugar industries were developing and perfecting practice in evaporation, filtration and crystallization. Metallurgy introduced refinements in methods of disintegration, leaching and mechanical separation. Spirituous liquors and essences were being distilled in fractionating apparatus that finds many a modern counterpart. Although a chemical industry was in early stages of evolution, most progress in the direction of the fundamental processes was being made in other,

then unrelated, lines of manufacture. Developments thus started have continued to the present time. These special industries have by the slow and costly method of experience brought many of the individual processes to a stage of efficient, practical production. It only remained for the chemical engineer to take the evaporator of the sugar refiner and adapt it to his special problem in alum manufacture. The ball and pebble mill of the metallurgical industry was made to do service in the cement plant. The alcohol still was modified for petroleum distillation and this in turn changed to meet requirements of the coal-tar industry.

Thus the chemical engineer has been the molder of industries. With the common bond of the unit process he has linked together what were formerly isolated lines of production. He has applied the work of both the theorist and the practical man. His knowledge of fundamental principles has given him a valuable insight into the rationale of the process, helped him to establish its limits of capacity and performance. Good judgment based on practical experience has enabled him to apply these processes intelligently and to operate them efficiently. The result, as we see it today in chemical engineering production, is a working balance of theory and practice.

Ninth National Exposition Of Chemical Industries

DISCUSSION of the Chemical Exposition in past years has usually stressed its value to the man in the street. This year our plea is for the man in the plant. Without in any way underrating the importance of the exposition's contribution to the education of the layman, it would be our desire to focus its appeal on those in our industries who are concerned with production. This year's effort can serve no better purpose than to demonstrate to the technical men themselves the really vital significance of modern technology, of new production methods, and scientific advances in theory and practice.

The Automobile Show and the Electrical Exposition are centers of popular interest that capitalize on their wide appeal to the general public. They are usually thronged with people from the street, curious persons and pleasure seekers. The National Exposition of the Chemical Industries, on the other hand, attracts a smaller attendance, but the idle and indifferent are notably fewer. The visitors come with a more serious purpose. The exposition strikes close to them. It concerns their livelihood; it deals with the processes, tools and raw materials with which they work.

There is a reciprocal value to the exhibitor also, or he would not be there. However, this value is indirect and cannot be measured in terms of orders and inquiries. It is institutional. The presence of the exhibitor is an open expression of his willingness to share in the problems of the technical man. The mere exhibition of equipment and materials is only the outward sign that the maker is interested in doing his part in making technology of greater service to industry.

There is no more effective way in which the management of the exposition can contribute to the progress of our industries than by thus bringing together these two vital factors in production—the maker and user of chemical engineering equipment.



Disintegration

Crushing, Grinding and Pulverizing

CRUSHING, grinding and pulverizing are vitally important operations in practically every chemical engineering industry using solid materials at any step. It may be necessary to reduce the particle size of a raw material in order to free it from impurities; it may be desirable to expose more surface to the action of a reagent; it may be imperative to have the final product meet a rigid specification as to screen analysis. Whatever the object, the problem of size reduction is one that requires careful study in order to insure the selection of the most economical equipment for the case at hand.

Quite naturally, an enormous amount of work has been done along these lines in connection with ore reduction operations, and a study of any of the standard texts on ore dressing will reveal the amazing variety of equipment which has been developed. Unfortunately the data apply to and the equipment is designed for capacities far in excess of anything encountered in the chemical industries, with the exception of cement and certain raw materials handled on a large scale.

Accordingly, the data are of limited applicability in

considering the grinding of most chemical products, not only because of the smaller amounts but also because of the wide variation in physical properties. The latter factor has been responsible for the development of much special equipment. Thus, in the paper industry, which is not ordinarily considered as one having many grinding problems, there are the following disintegration operations, many of which are conducted with special machinery: grinding of wood for mechanical pulp; chipping and crushing wood for chemical pulp; hogging waste wood for fuel; shredding rags, waste paper and pulp lags; disintegration of paper stock by means of beaters and jordan.

It is evident that each material presents an individual problem and that generalization is rather difficult. Nevertheless, this has been attempted in the articles which follow, not with a view to presenting data that will solve every possible problem but rather to indicate the field into which the problem falls and the factors that must be considered in its solution. The final decision will usually merit the advice of an engineer who has had practical experience with the material in question.

General Notes on Crushing and Grinding

Practical Consideration of Operating Characteristics and Fields of Application for Jaw and Gyratory Crushers, Crushing Rolls, Pebble, Ball and Rod Mills

BY B. W. ROGERS

Allis-Chalmers Manufacturing Co.

MECHANICAL comminution of material falls into two general classes; first, the metal-bearing ores that have to be crushed and ground to varying degrees of fineness to free the inclosed mineral, the ultimate purpose being a separation of the mineral from the gangue; second, the materials which are crushed and ground to produce a desired degree of fineness or to expose a greater surface. This class generally consists of crushed stone and sand for the building trades, cement, fertilizers, abrasives, paint pigments and chemicals.

The laws governing the two general classes of crushing and grinding are primarily the same, and the same methods and equipment can be applied for both with a few minor exceptions. Theoretical formulas have been evolved which are supposed

to establish definite relations between the energy required to crush and the surface exposed in crushing. The exponents of these formulas claim that capacities of crushing and grinding equipment can be based on the degree of reduction and the power input. However, a study of actual results obtained in crushing and grinding show a wide variation from the theoretical laws, and this variation can be explained by the fact that variable factors are involved which cannot be incorporated in the formulas.

Experience has taught that the best method of determining the proper size equipment to use for a given capacity and reduction is to draw comparisons between operating data of actual installations with suitable interpolations to fit the conditions being considered. Manufacturers

usually keep elaborate records regarding the performance of their machinery and the conditions under which each installation is called upon to operate, and from these records they can very closely approximate the performance and capacity of a contemplated installation when full information is at hand. In communicating with a manufacturer regarding crushing or grinding equipment, the following information is required to secure an intelligent recommendation:

1. Capacity in tons per hour or per 24-hour day.

2. Description of material as to its size and physical characteristics. If possible, submit a sample and a screen analysis which will show the percentage of fines as compared to the percentage of material of maximum size.

3. Desired fineness of the required product and the percentage of allowable oversize from a given ring or mesh.

4. Object of the reduction or the process of which the crushing and grinding is a part; also whether or not production of excessive fines will be beneficial or detrimental.



5. Whether it is intended to operate in closed circuit with screens or classifiers.

6. If floor space is limited, give dimensions of available space.

7. State source and supply of power, and if driving motors are required, mention voltage, cycle and phase.

8. If ball mills or rod mills are to be applied, state whether the grinding will be done wet or dry.

The field of primary crushers is dominated by the jaw and the gyratory types, which have a range of reduction according to their size, from pieces weighing several tons down to products of 1 in. for the smaller sizes. The crushing principle of these two types is well known and has been applied for many years.

For a given power input and first cost the jaw type has a larger ratio of reduction as compared with the gyratory, therefore the jaw crusher will be found more adaptable where a feed containing large pieces must be reduced to the smallest allowable size in one stage. For crushers having the same power input, the gyratory will show a feed opening of greater total area than the jaw type, but the dimensions of the jaw

crusher feed opening are such as to allow larger single pieces to enter, and the same is true of the discharge area. This makes the gyratory type more adaptable if large tonnage of uniform size is to be crushed. A distinct advantage of the gyratory crusher is that it will operate satisfactorily on a choke feed.

The crushing roll is the machine best adapted for secondary crushing and the general application is on feeds ranging from 1 in. to 3 in. The economical ratio of reduction is about 4 to 1, and in conservative practice a reduction of 6 to 1 is rarely exceeded. Rolls are not recommended to produce a product finer than 8 mesh. Where large capacities are involved, crushing rolls find an economical application as an intermediate stage between crushers and grinding mills. Crushing rolls are simple in operation, low in cost of upkeep, and when they are operated at full capacity and within the proper limits they show crushing costs that cannot be equaled by any other known crushing device.

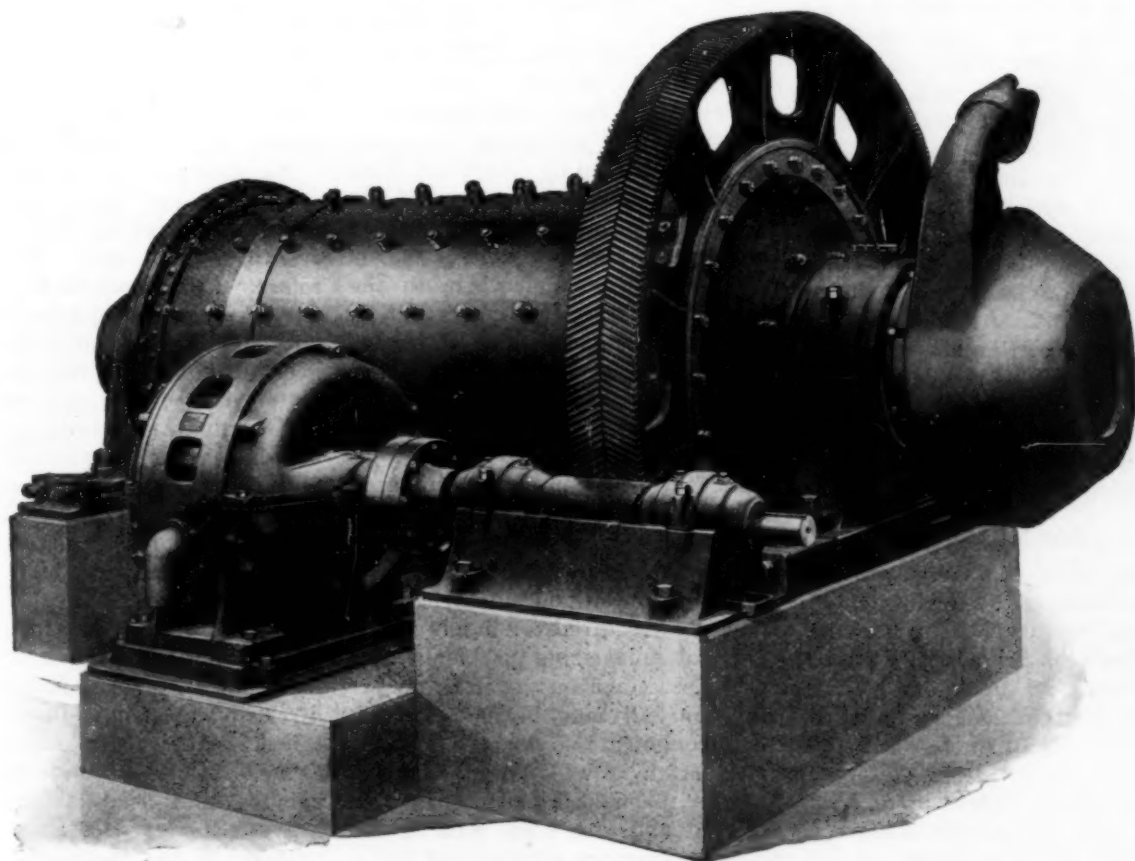
There is not a well-defined line between crushing and grinding or between the various stages, and the same is true of the application of the

various types of machinery. Each problem, therefore, should be considered individually and equipment selected that will maintain an economical balance between the capacity and reduction required, first cost and cost of upkeep and power.

In the last few years the ball mill and rod mill have been developed and demonstrated to such a degree that they have almost entirely superseded less efficient grinding machinery previously used, which consisted mainly of the stamp mill, Chilean mill, Huntington mill and various patented grinders of the roller or hammer type.

The introduction of the cyanide and flotation processes has been largely responsible for the development of fine grinding machinery, and with the exception of the cement industry, industries have been slow to adopt modern methods and fine grinding equipment.

The pebble mill was the first step in the development of fine grinding and consisted of a long shell revolving on rollers or trunnions, the grinding media consisting of rounded flint pebbles which are usually imported from Denmark and Norway. In the first applications the length of



MOTOR-DRIVEN WET-GRINDING ROD MILL



the mill governed the fineness of the product; but after the introduction of mechanical classifiers which separated the fines and allowed the coarse unground sands to be returned for regrinding, there was a tendency to make the mills in shorter lengths.

The first application of the ball mill was due to a shortage of good flint pebbles in this country, which led to the substitution of small iron and steel balls known as "ball-pebs." When a mill is charged with the same volume of steel as pebbles formerly used, there is an increase in power consumed at approximately the same ratio as the weights of the two grinding materials and the capacity is increased in approximately the same ratio. With the change in grinding media, the mills were redesigned and made considerably heavier and stronger with the bearings and gears proportionately larger to carry the increased load. The ball mill is an outgrowth of the ball-peb mill and is characterized by being much shorter in length than either the pebble or ball-peb mill. The ball mill is designed to take a grinding charge of balls ranging in size up to 5 in. diameter and feeds as large as 2½ in. are reduced successfully.

The pebble mill was used extensively in the cement-grinding industry, but in recent years has been largely superseded by a combination of the ball mill and ball-peb mill which is used both in the wet and dry process and on the raw and finished sides. The combination mill is built with a division head or diaphragm about one-quarter of the distance from the feed end, and this short section is charged with large forged steel balls. After the coarse feed receives a preliminary grinding in the first compartment, it passes into the long section charged with small balls, where it is ground in one pass to a fineness that meets the market specifications.

ROD MILLS

The rod mill is a comparatively recent development in grinding machinery and when applied within its limits it has been demonstrated to be more efficient than the ball mill. The rod mill is made in lengths approximately twice the diameter and the grinding charge is made up of rods varying in diameter from 2 to 4 in. and the length of the rods is slightly less than the working length of the shell. The rod mill has been found particularly adaptable when working on feeds less than 1 in. and pro-

ducing products from 40 to 80 mesh. The ground product from the rod mill shows a uniformity of size, with a minimum of oversize and fines as compared to ball mill products.

DRY AND WET GRINDING

Materials that must be ground dry often appear to be quite dry when in reality several per cent of surface moisture is present, which retards fine grinding due to the material coating on the balls and making their action ineffective. It is quite important that the surface moisture content be reduced to 1½ per cent or less before dry grinding is attempted. Where dry products are required to be ground to all minus a given fineness, closed circuit arrangement with vibrating screens is advisable up to about 80 mesh. Screening reaches its economical limit at about 80 mesh because of the large screen surface required and the high cost of screen replacement. Finely divided dry material lends itself readily to air classification and

closed circuit arrangement with air-separating devices can be successfully applied to fine dry-grinding.

Wet grinding is usually accomplished with a 30 to 50 per cent moisture content, and is used where water is not detrimental or is possibly an essential ingredient in the subsequent treatment of the pulp. Wet grinding eliminates the dust nuisance and creates a much more efficient grinding condition within the mill; furthermore, a wet pulp can be sized with simple mechanical classifiers.

Quite often batch grinding in ball mills is resorted to when extremely fine products are required. This method is slow and inefficient due to the time required to charge the batch and separate the ground product from the grinding media. Dry battery manufacturers are grinding compounds approaching 600 mesh fineness in mills of the continuous feed and discharge type at considerably reduced cost as compared to the batch methods formerly used.

Pulverizing

General Survey of Methods of Pulverizing and the Many Classes of Materials Encountered in Industrial Uses

BY HARLOWE HARDINGE

Vice-President, Hardinge Co., New York

A GREAT MANY LAWS of crushing have been worked up with carefully calculated formulas and substantiated by laboratory tests and some operations in the field, but there are so many variables that these laws, while they work in one or two cases, are of no value in the majority; hence it is necessary to rely upon empirical rules set up as a result of field operations entirely. Laboratory tests often point the way, but they also are the cause of many failures due to giving incorrect information when compared with continuous operation on a much larger scale, as is necessary in practice.

Like many other industries, the knowledge required for handling the principal pulverizing problems cannot be set down on paper to an extent that all may benefit, for too many complications occur.

An attempt will be made here, however, to make a broad survey of the field and give some idea of the problems that are encountered and a view of the principal ways of solving them.

Broadly speaking, we are en-

countered with the grinding of wet, dry, brittle, tough, hard, soft, sticky, dusty, light and heavy materials.

As illustrations of wet material ground, we have gold, silver and copper ores ground to extract the mineral therefrom—also lithopone and colors. In the case of dry grinding, we have cement clinker, silica and silver. Feldspar and enamel frit are good examples of grinding a brittle material. Iron borings and graphite are examples of grinding tough materials, while carborundum and emery are classed as hard. Talc, fullers earth, clay and chalk are put in the class of soft materials, while certain sodium salts, pitch and resin are sticky.

Most of the above materials when ground dry are dusty and provision must be made to guard against a dirty plant from these sources. Wood shavings and charcoal are typical of light materials, while barytes and lead skimmings are heavy.

Many of the above materials are required in different stages of fineness for different purposes, while others are ground to only one speci-



fication. However, the classifications as given here cover the entire field for all materials. These classifications may be reduced to: unclassified products; uniform size of product, either granular or fine; angular product; flat flakes; shreds.

An unclassified product is one where the grinding is accomplished without particular regard to the gradation of the product; that is, the percentage of the total on any particular mesh. The specifications usually cover only one screen size.

Then there is the requirement for uniform sizes, such as salt for table use. Here it is desired to grind without producing too many fines, for these have to be thrown away, put back in the process or sold at a lower price. In the case of fine grinding, feldspar for pottery uses is a good example, as the specifications call for a product that contains less than 0.5 per cent on 140 mesh.

Grinding emery or carborundum for abrasive use illustrates the case of grinding to obtain an angular product. It is desired that the sharp corners be retained during the grinding process, otherwise the product will lose much of its value.

In the case of obtaining flat flakes, a good illustration is flake graphite, used in crucibles, as well as for

lubrication purposes. The grinding action here must be one mainly of sliding and not crushing.

In the case of shredding or fiberizing, an illustration is the freeing of asbestos fiber from the rock, so that the fiber is discharged in as long threads as possible, and not broken up as would be the case with improper shredding.

METHODS OF GRINDING

In general, there are three main processes of grinding or pulverizing. First is the batch method where the material is dumped into the grinding device and after operating for a predetermined length of time, is discharged in the ground state. The second is the continuous open circuit method, whereby the material is fed in at one end, and grinding occurs continuously—that is, the machine does not stop to discharge the product, but the product discharges at the other end in a continuous stream, at the same rate as it is fed. The third is similar to the second, with the exception that the product after leaving the circuit goes to a separator, and this separator classifies the finished from the unfinished and returns the unfinished back to the mill for regrinding. In wet grinding, classifiers are used;

when grinding dry, vibrating screens or air separators.

OPERATING REQUIREMENTS

The principal requirements of a pulverizing device are: (1) It should be as fool-proof as possible. It stands to reason that the simple requirements make it possible to use a simple mill, while specifications calling for very uniform product, or extremely fine product, make the problem more difficult. (2) The power consumption should be as low as possible. Of course, the finer the grinding, the more power it is going to take per ton to do this work, but this power consumption should be carefully watched to see that it compares favorably with similar operations. (3) The apparatus when once set up and regulated should remain substantially in this condition, and not be affected by minor changes in the quantity of the feed, or atmospheric conditions. (4) One of the most important considerations of all where production must be based upon continuous operation is the period of shutdowns required on account of breakage or failure on the part of the operating device to operate continually under normal operating conditions. (5) It is also necessary to note in the case of special mechanical processes if the material going through is going to injure the mill, such as an acid or strong alkali, or if the grinding operation of the mill itself will either discolor the product or cause contamination due to injection of foreign elements to an extent which would change the chemical characteristics.

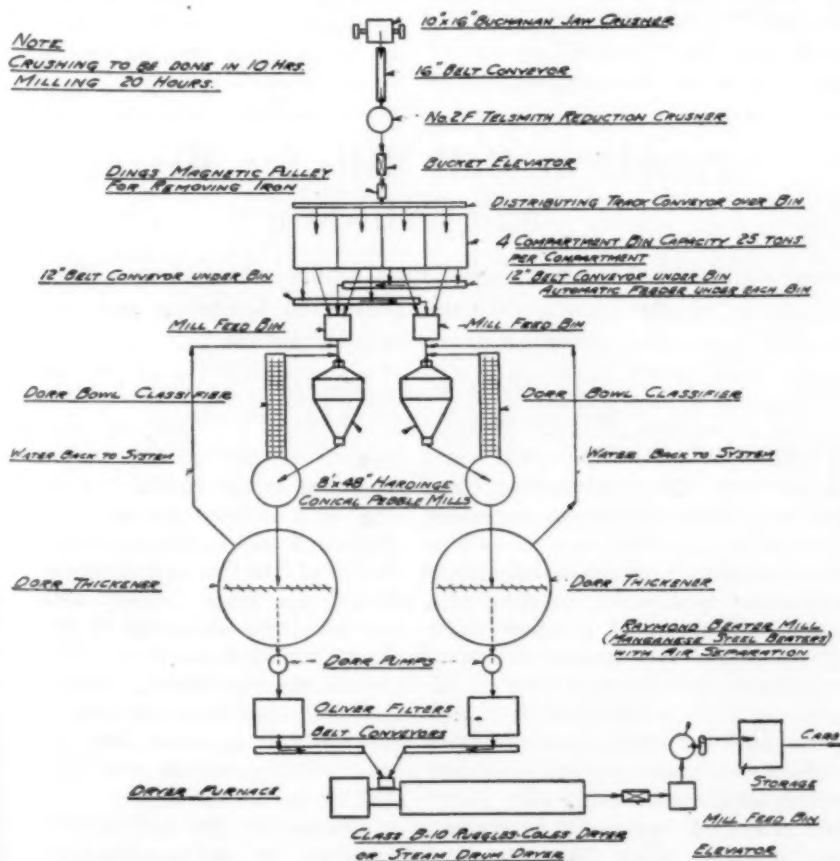
VARIABLES TO BE CONSIDERED

Taking into consideration the variables, some of which have been mentioned above, it is well to outline what will be encountered in any case.

1. Capacity. As a general rule it is found that the greater the capacity per mill unit, the greater is the efficiency of grinding.

2. Character of material. Sometimes materials of apparently the same physical characteristics vary 200 or 300 per cent in their resistance to grinding, and a knowledge of the characteristics of each material encountered is therefore essential.

3. The size of the material going through the mill is very important, for unless the grinding media are adjusted to the size of the feed as well as the product desired, the



TYPICAL LAYOUT FOR WET GRINDING FELDSPAR OR BARYTES



Size of Mill	Floor Space	Approximate Weights, Lb.			Hp. to Run	Size of Motor, Hp.	Capacity in Tons Per Hour			
		Mill	Lining	Ball Charge			1½ in. to 8 Mesh	1½ in. to 48 Mesh	1 in. to 65 Mesh	1 in. to 200 Mesh
2 ft. x 8 in.	3 ft. x 5 ft.	750	375	600	1	2	1	1	1	1/10
3 ft. x 8 in.	5 ft. x 7 ft.	3,600	1,400	1,000	5	7½	1	1	1	1/5
4½ ft. x 16 in.	7 ft. x 10 ft.	6,600	4,800	4,500	18	25	2	1	1	1
5 ft. x 22 in.	9 ft. x 10 ft.	10,200	7,000	7,500	30	35	3	2	2	1½
6 ft. x 22 in.	10 ft. x 11 ft.	12,000	10,000	12,000	45	50	6	4	5	3
7 ft. x 22 in.	11 ft. x 12 ft.	14,000	14,000	20,000	70	75	10	7	8	5
7 ft. x 36 in.	11 ft. x 13 ft.	15,000	16,300	27,000	90	100	12	8	9	6
8 ft. x 22 in.	12 ft. x 14 ft.	20,500	17,700	30,000	100	100	14	9½	11	6½
8 ft. x 36 in.	12 ft. x 14 ft.	22,000	19,400	34,000	135	150	18	14	16	11
8 ft. x 48 in.	12 ft. x 15 ft.	27,400	22,600	38,000	170	175	24	19	21	15
10 ft. x 48 in.	13 ft. x 16 ft.	40,000	35,000	68,000	300	350	45	35	38	25

operation will be far from efficient. In some cases, it is desirable to carry on the grinding in a way which is known as step reduction, that is, one mill unit follows another, the first doing part of the grinding and the next unit finishing. Either one or both may be operated in closed circuit with suitable classifiers.

4. The character of the product desired must be carefully considered. Some materials break down readily to a given size and then are hard to reduce below that point, while with others the opposite is true.

5. There is a vast difference between wet or dry grinding of the same material. While the ultimate capacity may not vary appreciably, the character of the product might be materially altered to obtain the same physical characteristics, hence it is sometimes necessary to operate in a mill under widely different conditions.

6. The nature of the discharge from the mill must be carefully watched, both in closed and open circuit operations. In the case of open circuit grinding, this is the determining factor, as the material is finished as it is discharged. In the case of closed circuit grinding, the efficiency of operation is largely determined by watching the mill product, for if too much of the finer material is discharged, the classifier or separator is not working to capacity, while if too little is discharged, the mill itself may choke up, having too much over-size going back with the initial feed, and ultimately build up too great a load for the mill to handle.

7. The human element. No matter how fool-proof any pulverizer may be, its operation is largely dependent upon the intelligence of the operator. While it is not necessary in the case of all pulverizers to employ high-grade mechanics to operate the mill efficiently, it is essential that when the mill is set up and operated, some one with a fair degree of common sense should oversee the operation and determine how it should

function in the future, then turn it over to the more or less unskilled laborer to be operated along the lines that will give the desired product with only a minimum expenditure of energy.

OPERATING SPECIFICATIONS

In order to give an idea of the variation which will occur with only one material, examine the accompanying table which shows the various sizes of one manufacture of mill. This table is based on the grinding of medium hard limestone. Other materials would be softer or harder, depending upon their characteristics. Feldspar may be half again as easy to grind, while graphite would have a capacity of about 0.1 of the range given here. Examine for a moment even the range encountered here. Take, for instance, the operation of the 5-ft. mill with a feed of 1½ in. maximum and reducing this to all passing 8 mesh with the normal amount of fines, which in this case would run

about 30 to 40 per cent through 200 mesh. The capacity would be in the neighborhood of 3 tons per hour, while this same material reduced from 1 in. to all through 200 mesh would have a capacity of only 1½ tons an hour. If, on the other hand, we take this same material from 1½ in. as first illustrated right down to 200 mesh, operating of course in closed circuit with a classifier, we should obtain hardly more than ¾ to 1 ton per hour.

The subject of grinding is an extremely complicated one, but there are methods of obtaining very close approximations as to what may be expected in the various fields, but these methods are gained only through operating under similar conditions. It is well to consider the fact that when studying a grinding problem there are many variables. All the major ones at least should be taken into consideration before determining upon the type of mill to be used, as well as how it is to be operated.

Pebble or Ball Mills for Mixing and Grinding

Some of the Factors Affecting Fine Grinding, Including a Discussion of the Desirability of Combining Grinding and Mixing in a Single Operation

BY H. F. KLEINFELDT

Secretary, Abbé Engineering Co., New York

THE ball or pebble mill, as a medium for pulverizing and grinding either dry or wet materials, is quite well known and is coming more and more into use in the various industries because of its simplicity, low maintenance cost, low power consumption, the elimination of expert attendance and the fact that it requires very little attention during its operation. Its application to mixing problems, although not quite as general, is also commanding very favorable attention, because it produces a very uniform mix. There is, however, one application that has not

been developed to the same extent, and that is the combining of grinding and mixing in one operation. Although this is done in quite a number of plants throughout the country, I believe many opportunities for utilizing this advantage of the pebble or ball mill have been either neglected or overlooked. Before considering the latter subject, it might be well to go into the principles governing grinding and mixing in ball or pebble mills.

Essentially, the ball or pebble mill consists of a revolving cylinder usually lined with a material that



will withstand impact and abrasion. The cylinder is partly filled with a charge of flint pebbles, porcelain balls, metal balls or other freely movable reducing bodies. The revolving of the cylinder causes the balls or pebbles to rise on one side of the cylinder until the force of gravity overcomes the centrifugal force. The pebbles then begin to roll and tumble to the bottom of the cylinder and in this way a combined impact and attrition effect is produced. The speed at which the best grinding efficiency is produced will vary with the diameter of the mill, the coefficient of friction of the material that is to be ground or mixed, the size of feed and fineness of finished product desired.

The ideal condition for fine grinding is where the peripheral speed is such that the pebbles or balls will be carried up to a sufficient height, so they will roll and tumble over one another. It might be stated at this point that the foregoing does not apply to ball mills which are used for the preliminary crushing of large pieces of hard material. In a case of this kind, it is desirable to depend to a great extent on impact and consequently larger balls are used and the speed increased to the point where the balls actually drop through space.

FACTORS AFFECTING FINE GRINDING

As this article is especially devoted to fine grinding and mixing, we shall take up the question of what effect variations of different kinds have as follows:

Size of Balls or Pebbles.—Too little attention is given to the proper size of pebbles for the grinding of a certain kind of material to a given fineness. If the grinding consists in the reduction of a fairly coarse material, say about $\frac{1}{4}$ to $\frac{1}{2}$ in., and it is not necessary to grind the finished product very fine, a large pebble or ball should be employed. If the feed consists of a mixture of coarse and fine material, it is advisable to take a mixture of small and large pebbles or balls. If the material is fed in a fairly fine condition, say from 8 to 20 mesh, and the resulting product is to be extremely fine, it is advisable to use small pebbles or balls. In other words, the idea in fine grinding is to have as many points of contact as possible with a pebble or ball of sufficient weight, so that the impact is sufficient to reduce the material to be ground. It can be readily seen from

this that the ideal condition is obtained with maximum points of contact and with pebbles or balls of sufficient weight to grind or pulverize the material. This is true in either wet or dry grinding.

Moisture Content.—In the case of dry grinding, the moisture content of the material to be ground is very important and it has been definitely established that greater efficiency is obtained when the material is as free from moisture as possible. If the moisture content is increased, the time of grinding is invariably increased, and if there is an excessive amount of moisture present, the material will have a tendency to "ball" or pack.

Proper Grinding Charge.—There is a considerable difference of opinion as to what constitutes a proper

There are many instances in the design of plants for conducting mixing and grinding operations where the combining of the two would effect a considerable saving in expense of installation and operation. Have you considered this possibility from the viewpoints of reduced labor charge, more uniform mixing, increased tinting power when mixing colors, and freedom from contamination?

grinding charge and the relation that the volume of the pebbles should bear to the total volume of the mill. In the case of dry materials, however, it has been the writer's experience in testing out a great many different materials that there is a certain definite relation among the total volume of the mill, volume of material and the volume of the pebbles as follows: The cylinder should be approximately half full of pebbles or balls and then a sufficient amount of material put in to slightly more than fill the voids or interstices in the mass of pebbles.

In the case of wet grinding—that is, the grinding of a solid in a liquid—the general practice is to charge the mill approximately half full of pebbles with sufficient material to bring the level slightly above the center. Some users of mills, in wet grinding, charge the cylinder with material about three-quarters full, which usually results in an increase

in grinding time but a somewhat greater production per batch from the same size machine.

Consistency of Material in Wet Grinding.—For wet grinding, the material should be of about the consistency of a heavy cream, or perhaps to illustrate this a little better, in the case of an ordinary house paint, slightly heavier than is best for regular brush work.

It can be readily seen from the foregoing that the principle involved in the grinding of materials would necessarily be a good one if applied to mixing, and for that reason this machine is used extensively where extremely intimate mixing or blending is essential and it is a proved fact that the pebble or ball mill will give a better mix than any other type of machine.

COMBINED GRINDING AND MIXING

This leads us to the point to which I wish to call particular attention—that is, combined mixing and grinding in pebble or ball mills. This is a subject that has not been given enough serious thought. There are many instances in the design of a plant where mixing and grinding operations are performed where the combining of these two would effect a considerable saving in expense of installation and operation. The general advantage to be gained in combining grinding and mixing are as follows:

1. The labor charge is materially reduced, as the material will have to be handled only once.
2. On account of the many points of contact a greater uniformity in the mix is secured.
3. In cases where a color is to be mixed either with other materials or other colors, the increased grinding which the material will receive, during the time it is in the mill, will produce a greater tinting power and consequently a smaller amount of color can be used to produce the same effect, as it is a well-known fact that the dispersing or tinting power of a pigment is proportional to its fineness.
4. In the case of pharmaceutical and food products, it is usually essential that the product be kept clean and free from contamination. The pebble or ball mill, therefore, is the ideal machine to use, as it is practically hermetically sealed during the operation.
5. In the case of wet grinding and mixing, the foregoing holds good and in many cases a greater saving can



be made, as for instance in the case of the paint, varnish and lacquer industries.

AN EXAMPLE IN THE PAINT INDUSTRY

In the grinding and mixing of paint, the usual method has been to pre-mix the pigment with the vehicle, then grind it through a paint mill and then thin down in a final mixer. These three operations can be combined in one in the pebble mill, as the pigment and vehicle can be introduced simultaneously, and if necessary, after grinding, a thinner can be added right in the mill. Another advantage is the fact that with such a large number of pebbles and the many points of contact which are effected during the grinding of a charge, a thorough incorporation of the pigment in oils will naturally follow.

A few of the uses in which pebble or ball mills serve for combined grinding and mixing are flooring compounds, drugs and chemicals, face powders, colored cements and also in the blending and standardizing of dyes, dry colors, etc. It might also be remembered that these mills can be used on either alkali or acid materials, as the linings can be made to resist almost any condition that may arise.

There are some industries which might find a greater use for this type of machine if they would realize that the mills can be built so that either a heating or cooling effect of the material can be accomplished, the material either ground under a vacuum or pressure or in the presence of a gas. In this way very often chemical reactions may be obtained at the same time grinding and mixing are accomplished.

be properly cooked or chemically treated.

Chipping of the wood is one of the most important steps in the manufacture of good strong pulp and the elimination of waste. This cutting or chipping process is done by a machine commonly termed a chipper, of suitable size, as shown in Fig. 1, consisting of a revolving disk upon which is mounted three or perhaps four flat steel knives, which are set at different angles and produce the size of chip desired. These knives in the rotating process cut against a bed knife usually placed at the bottom of the charging spout. The size of the chip usually used is from $\frac{3}{4}$ - to $\frac{7}{8}$ -in. length. These should be uniform in size as to length, width and thickness, in order to cook uniformly and produce the greatest yield. It is therefore important that the chipper be kept in first-class condition at all times. Chippers in general work on the same principle, but with a great variation of results, and widely different results are obtained from the same chipper, due to various causes.

Chipping Wood for Chemical Pulp

One of the Disintegration Operations of the Paper Industry in Which Waste May Be Eliminated Through Careful Control

BY A. K. HINDS

General Manager, Carthage Machine Co., Carthage, N. Y.

CHIPPING of wood for chemical pulp is of interest not only as representing one of the important applications of disintegration in the paper industry but also because it is a process in which a great deal of unavoidable waste often occurs. The elimination of this is particularly desirable in view of the possible Canadian embargo that may be placed on pulpwood.

It is necessary that the wood for

chemical pulp should be clean and properly rossed or barked, as bark or knots are detrimental to the manufacture of strong pulp if allowed to pass to the digester in only the smallest amounts. Spruce, hemlock, balsam, Southern pine and some hardwoods are utilized, and in the preparation are treated fundamentally the same. This preparation consists of cutting into small chips

in order that the wood may

FACTORS AFFECTING QUALITY OF CHIPS

Some of the factors that affect the quality of the chips are: The shape of the chipper spout and the relation of its diameter to the diameter of the wood; the clearance between spout and disk; the setting of the bed knife; the speed of the disk (usually run at 250 to 300 r.p.m.); the condition of the face of the disk; the keenness and setting of the knives; their bevel and thickness for different operating conditions; the length and shape of the wood, and the manner in which it is fed to the spout.

Enough stress cannot be given to the importance of each of these, as they affect the uniformity of the chips, and the amount of waste, consisting of sawdust and rejections produced.

If it were possible to make the proper chip in the chipper, there would be no use for crushers and screens. As it is, the usual installation consists of a chipper, chip screen and chip crusher.

There are two types of screens used, the flat or shaker type screen and the revolving screen. The latter is now more universally used and found much more efficient. Good results are obtained by screening first and then passing the rejections from the screen to a crusher.

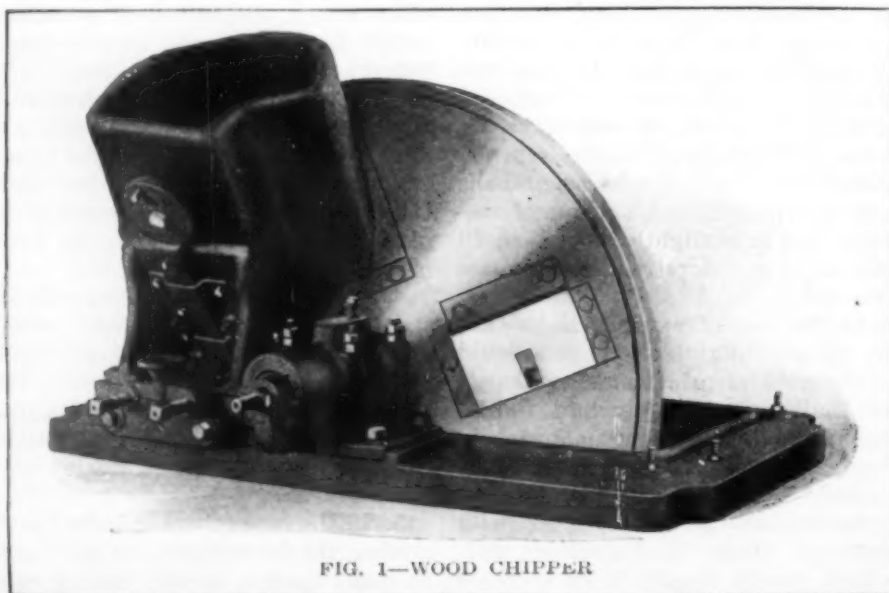


FIG. 1—WOOD CHIPPER



Disintegration of Wood for Mechanical Pulp

Preparation of Ground Wood Pulp, Involving Fiber Separation by Purely Mechanical Means, Has Presented Many Unusual Problems in the Development of Efficient Equipment

BY JOHN J. CASE

Chief Engineer, Baker Manufacturing Corporation, Saratoga Springs, N. Y.

PULP, from which one of our most common yet indispensable commodities is made, consists of tiny cellulose cells of which wood is composed; disintegrated and separated from their natural binders, and woven into a web; which when dried constitutes paper.

Pulp is divided into two distinct classes: chemical and mechanical.

Chemical pulp is further subdivided into sulphite, sulphate and soda. The manufacture of this class of pulp consists of a process whereby the wood is subjected to the reaction of certain chemical agents, while heated and under pressure in a large boiler or digester.

Mechanical or ground wood pulp is produced by a purely mechanical effort, that of friction between a moving grindstone and a stationary piece of wood.

The wood itself must be of suitable quality in order that satisfactory pulp may be ground. Spruce is the best material, followed in order of quality of pulp produced by fir, hemlock and certain classes of pines. Woods which contain a large amount of pitch do not make satisfactory pulp, for while they can be ground, they invariably gum the paper machine wires, so that it is impossible to maintain production.

SAWING AND BARKING PREPARE WOOD FOR GRINDING

The first operation relative to ground wood production is to saw the logs to the required length to fit the grinders. Next, the wood is subject to a rolling and tumbling operation in a barking drum, which removes the bark. The best results are obtained when the wood is barked in hot water, as the product is much cleaner and there is less loss of fiber from the broomed ends of the sticks.

After being barked, the wood is inspected for knots and rotten spots, as too many knots and dead spots discolor the pulp and glaze the stone so that very frequent dressing is required.

The wood itself is composed of a

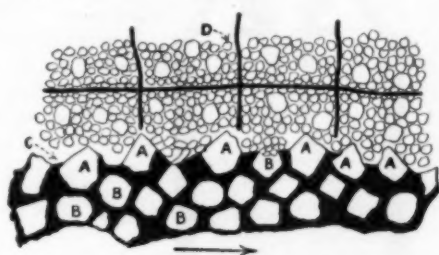


FIG. 1—MECHANISM OF GRINDING

mass of cellulose fibers held together by a binder called lignin. Between these cells are small canals or channels which conduct the sap and pitch through the mass. An analysis of the constituent parts of spruce is approximately as follows:

	Per Cent
Cellulose	50
Lignin	30
Carbohydrates	16
Protein	1
Resins or fats	3

The cellulose fibers themselves are long and narrow, always running lengthwise of the stem or trunk of the tree, averaging about 3 mm. in length. When separated from the lignin they are apt to curl up and easily mat together when shaken or poured out or run onto the machine wire.

In the grinding process, the cellulose fibers are separated from the lignin, which is softened and washed away. The other constituents are also evaporated or decomposed by the heat generated by the grinding process, which leaves available the cellulose fiber, of which the pulp is composed.

The stone is composed of natural sandstone, and should be granular in structure, so that as some of the grits are broken and worn off, fresh sharp ones will be presented. The actual grinding operation is quite clearly shown in Fig. 1, in which A represents the stone grits held by the natural binder, B indicates voids between the grits in the stone, C shows indentures made in the stone by the stone dresser, D indicates the cellulose fibers.

As the stone passes over the face of the wood block, the stone grits A catch some of the wood fibers D, which have been partly loosened by

the heat and strain generated by friction, and pull them out.

Then the indentions C and voids B act as small reservoirs, and carry the loosened fiber along to the pit, where it is washed out. It is therefore necessary to have the stone face submerged, otherwise the ground fiber would fill up the voids and glaze over.

Pitchy wood or hard knots tend to fill up the voids and indentures, and therefore retard grinding.

As we have seen that the grinding process consists in disintegrating the cellulose fiber from the lignin, the next operation is to carry this operation out in a practical way, which is accomplished by use of the grinder.

APPLYING THE PRINCIPLES TO COMMERCIAL PRODUCTION

It has been found that production is facilitated and the length and character of the fiber can be varied at will by applying pressure to the wood block. It is therefore necessary to devise a means of holding the block and applying the required pressure. This is accomplished in principle as shown in Fig. 2.

The wood blocks are placed in the pocket, after the press plate has been raised by means of hydraulic pressure, controlled by a valve. Then the valve is reversed, and the pressure thus released pushes the piston and press plate downward, forcing the wood against the moving stone. It has been found by experiment that the best grinding pressure will average about 30 lb. per sq. in. of pocket area.

Under these conditions it will be observed that a considerable amount of friction is bound to occur, due to the sliding motion between the stone and the wood, and therefore a large amount of power is required to keep the stone in motion. A considerable amount of the energy expended is also converted into heat units, therefore it is necessary to keep the stone partly submerged or mired in water, otherwise the heat generated would burn the fiber and render it useless.

However, this heat has a very beneficial effect on the wood. As the stone revolves, a film of water is carried around on the face of the stone, and when it comes into contact with the wood, the resultant friction between the stone and the wood converts the water into steam. This steam softens up the lignin, so that it is washed away, thereby loosening the cellulose fibers and as-

sisting materially in the grinding operation and enabling a longer fiber to be made. In many cases mills put in special apparatus for steaming the wood before it is ground.

As grinding is a purely mechanical proposition and consumes a considerable amount of power, it is, like all manufacturing processes, desirable that manufacturing costs be kept as low as possible.

DISADVANTAGES OF HAND-FED POCKET GRINDERS

In the past grinders have been built with three or four hand-fed pockets, using wood 24 to 36 in. long. This type of grinder requires constant attention, as the pockets, when ground out, must be reversed and refilled. In order that production be maintained, the attendant must sort the wood to get the pocket as full as possible, and then reverse the grinder valve to the grinding position. This means loss of available power, which, computed on a time basis, will run as high as 15 to 20 per cent under various operating conditions.

The grinder room as a rule is in semi-darkness and full of steam; the floors are wet and covered with slimy pulp, and there is no incentive for good workmanship. These conditions have been incentive to high

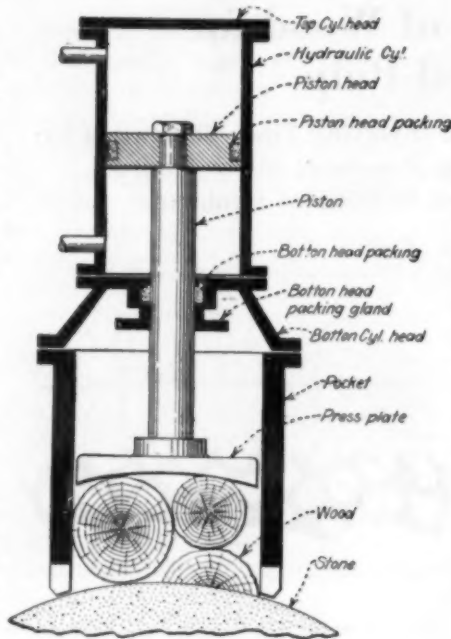


FIG. 2—GRINDER CONSTRUCTION

production costs and unfavorable labor conditions.

However, up-to-date manufacturers are installing the automatic magazine type of grinders, machines which require filling but twice a day, the magazines holding from 4 to 8 cords of wood. The charging of the pockets is automatic, with very little loss of time; the wood in the magazines is well steamed before grind-

ing; the grinder room is free from steam, and is dry and clean; and labor is reduced to a minimum, as in most cases one man can attend to four machines, except for the charging of the magazines. These machines have been the means of increasing production, decreasing manufacturing costs, and eliminating considerable labor trouble.

After being ground, the pulp is diluted with water to a consistency of from $\frac{1}{2}$ to 1 per cent and run through screens, which separate the slivers, etc., from the fine stock. It is then run through a decker or thickener, where the consistency is reduced to about 5 per cent. This operation washes out a considerable amount of dirt, etc., after which the stock is again diluted and run over a press, where it is lapped for shipment. In some cases the stock, after it leaves the washers, is run into a chest, mixed with sulphite and pumped directly onto the machine wire. This grade of pulp is used in our great daily newspapers and is termed newsprint.

The major portion of ground wood pulp is used in the production of this grade of paper; some is used in the manufacture of cheap grades of book, tag and tissue; and quite a large amount in the manufacture of board.

Secondary Crushing of Talc

Principles Involved Therein Apply Equally Well to the Solution of Other Problems

IN secondary crushing a greater variety of machines is used than in primary crushing, for more types are available and not all types are adapted to every variety of talc. Machines of this class are generally used to reduce the coarse crushed rock ($1\frac{1}{2}$ to $2\frac{1}{2}$ in.) fine enough to feed to the fine grinding machinery $\frac{1}{2}$ to 1 in. According to Bureau of Mines publication 213, by Raymond B. Ladoo, the most common secondary crushers now used are rotary crushers of various sizes, but rolls are much used; in a few plants hammer mills and disintegrators, set to make a coarse product, are employed.

One of the fundamental principles of milling is that it is cheaper to crush than to grind, but it is not economical to try to do fine grinding in machinery designed for secondary crushing.

It is always a good policy to make as fine a product as possible in secondary crushing. If this cannot be done by one machine, it may be done in two or more stages. If a two-stage reduction is used, a screen having openings the size of the final product desired should be placed between the crushers in order to remove from the first product all the material fine enough to pass the second crusher. This procedure follows out a second milling principle, that when material is crushed or ground fine enough for a particular stage it should be removed from the circuit, in order to lessen the load on the next machine and to make its operation more efficient. Fine material mixed with coarse cushions the crushing or grinding effect of any machine for the same reason that it is difficult to crack a nut resting on a pillow. In mills having small capacity it may

not always be worth while to observe this principle, but in large mills observance may be very important. For the secondary crushing of talc, rolls are not usually as efficient as rotary crushers, especially in mills of small or moderate size, as the ratio of reduction obtainable with rolls is much less than with rotaries. Thus, where a given reduction may be made in one stage in a rotary, two or more stages may be required with rolls. Feed to rolls may not be much greater than $1\frac{1}{2}$ in. in size, whereas rotaries take much larger feed. The ratio of reduction with rolls is ordinarily not much over 4 to 1; with a slippery mineral like talc it may be only 3 to 1.

The most common size of product made in secondary crushing lies between $\frac{1}{2}$ in. and $\frac{1}{4}$ in., but extremes of $\frac{1}{8}$ in. to 1 in. were noted.

Where the secondary crusher product is to be used a feed to tube mills or pebble mills, it is not necessary to crush as fine as where the fine grinding is done in roller mills, emery mills, or in some forms of pulverizers and disintegrators.



Mixing and Agitation

EFFICIENT mixing, whether of solids with solids, solids with liquids or solids with gases, is accomplished in a wider variety of equipment than any other unit process. The reason for this is fundamental. Mixing processes must vary with the differences in the properties of the substances dealt with. With evaporation, distillation and filtration, the individual problem has characteristics that differ but slightly from the average. Not so with mixing and the other processes of integration. Here an equipment has been evolved for a single operation that is often of use in no other operation.

This condition further explains the lack of fundamental research from which general principles could be

established. So now when a new problem presents itself, it is only by a process of trial that a machine can be identified as appropriate for this work. Probably the time will never come when we can do without trials, but the more we tend in that direction the more complete will be our mastery of technique. So our cry is, "Fundamental research in the integration processes."

The articles published in this section deal with the two fundamental divisions of the subject and attempt to indicate factors that are important for users of this equipment. They will serve as a brief but comprehensive picture of the types of equipment and in general of the status of the art. Specific uses of this equipment will have place in subsequent issues.

Equipment Used for Agitating and Stirring

Description of the Various Types of Machine Available for Accomplishing This Work, With Some Remarks as to Their Operation and Use in Industry

BY CLIFFORD H. TYLER

The Dorr Company, New York City

PROBABLY the first axiom taught the new student in a chemical laboratory is the fact that for a chemical reaction to proceed smoothly to completion, the reacting substances must be brought into intimate contact. To effect this, he stirs his solution with a glass rod, shakes his test tube, or rubs his solids together in his mortar with a pestle.

It is but natural that, when the discoveries of pioneer chemists were first used to found a new industry and their laboratory experiments were magnified to a commercial scale, these same methods of mixing should remain in the enlarged picture. It took considerable time for prices and practices to approach an equilibrium and for inevitable competition to underscore that important factor, efficiency.

The profession of chemical engineering is young enough to see still in operation many of the first contrivances for agitating and stirring. It is the purpose of this paper to review, in a general way, the development of apparatus and the all too little work that has been done on the theory of mixing.

Although problems of agitation may involve materials in all stages from solid to gaseous, the great mass of operations may be divided into the two systems, liquids with liquids and solids with liquids. The former is plainly a chemical problem; but the allied field of metallurgy has contributed largely to the handling of the latter.

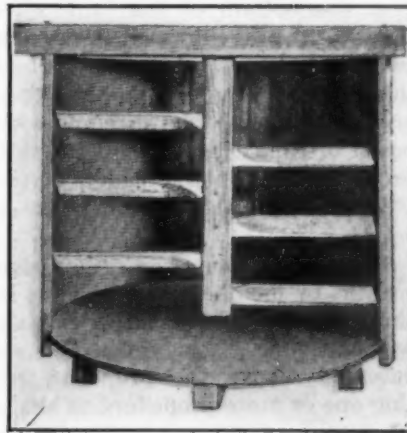
TYPES OF PADDLE STIRRERS

The first logical step after the manual stirring of a tank with a paddle was to apply power to the paddle. This, in the form of a revolving central shaft with cross-arms, forms the basis of one of the largest classes of stirrers. Although primitive, and at first thought seemingly crude, recent experiments, notably by Dr. W. L. Badger of Ann Arbor, have proved the paddle stirrer surprisingly efficient in mixing mobile liquids (see *Chem. & Met.*, vol. 27, p. 1176; vol. 28, p. 1077). Using water and a saturated sodium chloride solution in a 5x5-ft. tank of 600-gal. capacity and a two-blade, 3x3-in. paddle shaved to a 45 deg. angle, Dr. Badger and his co-worker arrived at the following conclusions:

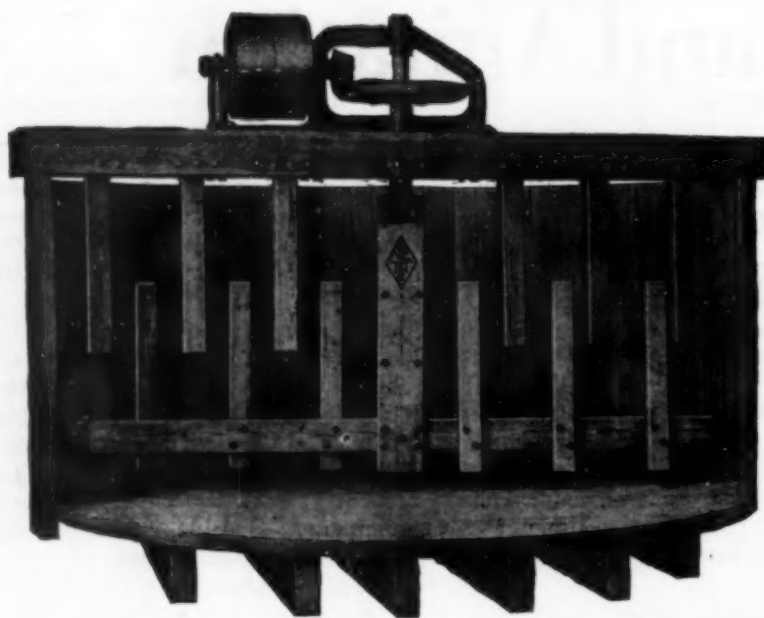
1. The plain paddle stirrer is much more efficient than usually supposed.
2. The 600-gal. tank was completely stirred in less than 1 minute at any speed above 22 r.p.m.
3. The appearance of the liquid is no measure of the stirring efficiency.
4. At speeds above that of minimum time of stirring, there is a rapid rise of power consumption.

Despite these expressions in favor of the simple paddle, the feeling is deep set that the swirling produced represents to a large degree motion of the entire mass rather than relative motion of its constituents and consequently wastes power. To break up the swirl, many modifications have been devised. Naming these will suffice to describe their operation:

1. Shaving the paddle as in the above experiments to give a vertical component to the resulting motion.



PADDLE STIRRER, WITH SHAVED BLADES



PADDLE STIRRER, GATE TYPE, WITH UNSHAVED BLADES

2. Baffles extending from the wall and staggered with the paddles.

3. Vertical teeth, rakes or pickets fastened to the paddles.

4. Two sets of paddles revolving in opposite directions about the same axis.

5. Paddles placed at the foci of ellipsoidal vessels.

6. Helical vanes along the walls to make the revolving fluid climb on an inclined plane.

HOW AGITATORS WITH PROPELLERS ARE DESIGNED

Propeller types of agitators are usually designed to revolve at higher speeds and to give a more violent disturbance than are the paddle types. In its simplest form, a two- or three-blade marine propeller revolves at the end of a central shaft near the bottom of the tank. The fluid is forced upward with some swirl and returns along the walls of the vessel. At the present time there are no data available to compare the power or time efficiencies of the plain propeller and plain paddle types, although such data should be interesting.

Propellers also lend themselves readily to modifications. These include mounting draft tubes with and without vanes, some of which are patented, above the propeller, setting one or more propellers on shafts off center; inclining the tank, and others. A propeller with a draft tube is the type usually used in ni-

trators, sulphonators and similar reaction vessels where heating or cooling coils are employed.

Under propellers might also be mentioned the helical screw revolving inside a draft tube, used for more viscous mixtures; and the helical ribbon fastened to the central shaft, but revolving close to the wall. The latter lifts the solution and throws it toward the center.

TURBINE AND OTHER TYPES OF AGITATORS

The turbine is really a special type of the paddle stirrer. The blades are so formed that the resultant force is practically all centrifugal, with small rotary and vertical components. The speed is high and the vessel is usually curved in such a way that the liquid will slide up the side of the vessel and form a downward current in the center. High speed is usually necessary for



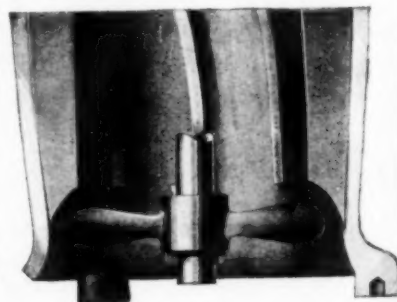
PROPELLOR TYPE AGITATOR, WITH DRAFT TUBE

complete mixing with this type of machine.

In addition to these more or less standard agitators and stirrers which are on the market in numerous designs, many special devices may be used if conditions warrant. Air or some other gas may be bubbled or blown through the mix, the container may be rotated or shaken, the liquids may be forced to cascade over a corrugated bed, or, if the solution is an electrolyte, the motion of magnetic flux may be utilized to effect mixing.

Systems for Mixing Solids and Liquids

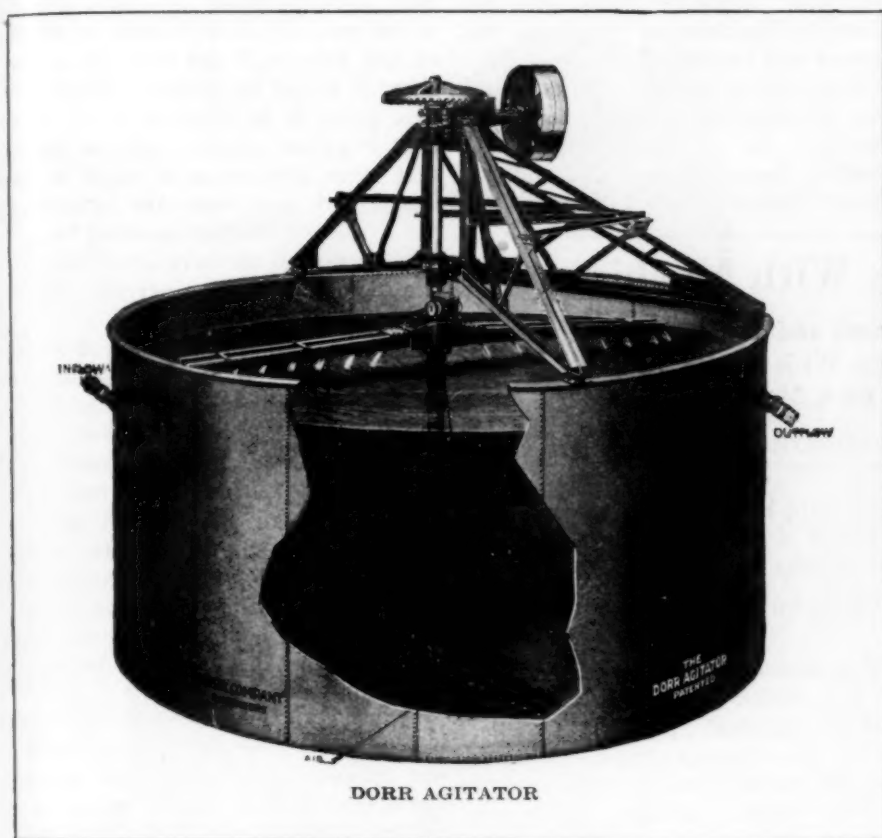
Experience seems to indicate that for stirring mobile liquids there is no great difference in desirability to favor any of the above methods. To disburse solids, however, even when very finely divided, requires special study and treatment to insure efficiency, economy of power and uniformity of mix, especially when the operation is continuous.



PROPELLOR TYPE AGITATOR, WITH VANES ON SIDE OF TANK

This agitation problem occurs in leaching, dissolving, extraction and digestion processes—which are basically very similar. It is generally assumed that the dissolving action is in two stages, the formation of a saturated solution of the dissolving material in the film immediately surrounding the particle and the diffusion of this film through the less saturated solvent. With this conception it is obvious that the velocity of the action depends upon: (1) Physical condition or nature of the particle. (2) Velocity of diffusion. (3) Strength of solution. (4) Rate of change of relative position of particle and solution. (5) Temperature of the solution.

Although this discussion is concerned only with the fourth of these considerations, it might be said in passing that for the first the material should be as fine as possible; for the



DORR AGITATOR

second, electrolytes and highly ionized substances diffuse most rapidly; for the third, the solvent should be kept as weak as possible, and for the fifth, increased temperature usually hastens action, often enough to warrant spending money to heat the solution.

The problem of efficient agitation was forced on metallurgists by close competition, but the need of a continuous method which would cut the time of leaching, decrease the power consumed and get a greater percentage of the metal was an effective spur.

One of the attempts along this line was the paddle agitator with air accessory. In this machine a current of pressure air was fed through the hollow paddle shaft and hollow blades, being discharged into the agitator vessel through perforations in the blades. The motion of the blades kept the mixture stirred up and the current of air served to form an upward current, carrying the solid material toward the top of the vessel, from which point it fell by gravity.

Perhaps it was the necessity of entrapping air in the cyanide solution to facilitate the dissolving of gold and silver that led to the use of the air lift as a means of agitation. It was, at any rate, at "ten-strike"; but, like most worth-while principles,

many designs were used before anything near perfection was attained.

EARLY AIR LIFT AGITATORS

The plain air lift as first used is illustrated by the Pachuca and Parral agitators. The former consisted of a cylindrical tank about 60 ft. high and 12 ft. in diameter, with the lower part in the shape of an inverted cone. The difficulty encountered was that the solids built up on the sloping sides of the cone, instead of feeding continuously to the air lift, then sloughed off suddenly, choking the air feed and stopping the action altogether.

The Parral tank was a plain cylinder about 42 ft. high and 25 ft. in diameter. Four lifts were placed symmetrically near the walls of the tank and discharged in a tangential direction, giving a rotary motion to the main body of solution. Building up of solids and high power costs has made this type almost obsolete.

AIR LIFT AGITATORS NOW USED

The Dorr agitator was the first to apply these correct principles of mixing. A cylindrical tank of any reasonable size is used with the inlet and outlet, for continuous agitation at the surface of the solution. A central revolving shaft acts as the casing of an air lift. Two radial, trough-like arms, or launders, with

perforated bottoms, extend from the top of this shaft and two arms with plow blades sweep the bottom.

The pulp, settling to the bottom, is pushed to the center by the plows, raised by the air lift, is then distributed uniformly over the surface by the revolving launders and settles slowly or quickly according to the size of the particle, to repeat the cycle. Chains dangle from the ends of the launders to prevent solids adhering to the wall and the plow arms may be raised to facilitate starting after a shut-down. Steam coils are often incorporated in chemical agitators to provide means for regulating the temperature.

While speed and intensity of agitation may be regulated, violent disturbance is unnecessary and often undesirable. For this reason power costs, both for air and plowing, are low.

For continuous operation, three or more agitators are usually connected in series with a difference in elevation of a few inches between successive units to give gravity flow. Having given the amount of material to be handled per unit of time and the lengths of time necessary for the required action to take place, it is a simple matter to decide from empirical data the size and number of agitators necessary.

Classifiers are often used for agitators in connection with the separation of the solids according to size and the washing of any granular material. The Dorr classifier consists of an inclined settling trough and a set of reciprocating rakes which gradually push the large settled particles to the upper discharge end while keeping in suspension the finer material to be overflowed. The Akins, Ovoca and Esperanza classifiers are similar to the Dorr, but have different mechanisms to force the oversize material up the incline.

CONCLUSION

The consideration of agitating and stirring practice to day seems to lead to two conclusions:

1. To mix mobile liquids of similar specific gravities, paddle, propeller and turbine agitators and modifications of these are quite efficient. There is no evidence that one type stands out as superior to the others, though research along this line is desirable.

2. Where the specific gravities of the constituents differ widely, as in mixing solids and liquids, an agitator which disperses the heavier



without swirling the entire mass is preferable. The air lift type, similar to the Dorr, accomplishes this by utilizing the force of gravity and seems the most efficient at the present time.

Acknowledgment for material used in this paper is made to D. M. Liddell and Liddell's Handbook of

Chemical Engineering and to the engineers and records of the Dorr Co.

Illustrations are printed by courtesy of the Dorr Co., Bethlehem Foundry & Machine Co., New England Tank & Tower Co., and the Hauser-Stander Tank Co.

Mixing and Kneading With Machinery

A Classification of Mixing Equipment and a Discussion of the Features of Good Mixer Design, With Some Pointers for the Purchaser of Such Machines

BY HAROLD B. VOLLRATH

Joseph Baker's Sons & Perkins, New York City

MIXING processes, with respect to the physical state of the materials to be mixed, may be classified under three general headings:

1. Mixing liquids together.
2. Mixing dry solids together.
3. Mixing liquids with solids.

The first, unless it be a problem of emulsifying, may be classified as agitating and stirring. The second, usually involving powdered or granular materials, might also be referred to as blending. Only under the third occur cases requiring both mixing and kneading, the subject with which we are here concerned. And under this heading, between wide extremes, runs a variety of mixtures from thin pastes to the toughest plastics, while some problems present a case of all three headings during one mixing operation, such as a solution which is evaporated through the plastic stage and finally into dry material.

Mixing machines, for purposes of description, may be classified in various ways, perhaps the most elementary being into these three types: (1) The mixing vessel rotates, (2) the vessel is stationary and one or more mixing elements rotate within the vessel, and (3) a combination of the two preceding types. The first is most widely represented by the familiar concrete mixer. Of the second and third, a further classification would be the operation of the machine on a vertical or horizontal axis. Of these there have been evolved such a wide variety, comprising so many styles and shapes of vessels and mixing elements, that the prospective purchaser finds himself confronted with a task in trying to select the type best suited to his mixing problem. There are nine ways of killing a cat, but some ways are better than others. There may be a number of different styles of mixers

that could be used with passable results on a certain mixing problem, but usually some one style is best.

POINTS TO CONSIDER IN SELECTING MIXERS

Fundamentally, that type of mixer is best which turns out the most perfect finished product at the lowest cost—merely simple efficiency. Usually the emphasis is on the quality of the finished product, its homogeneity, freedom from lumps, etc., and this may depend not only on the mixing ability of the machine but also on other factors such as the heating or cooling surface afforded by the mixer. In the cost factor, the same is true of mixers as of all machinery, that to the purchase price must be added maintenance charges throughout the life of the mixer. The prospective purchaser therefore should examine carefully the construction of the machine that he may know it is adequately strong and durable. And in the cost of operating the mixer, the relation of power consumed to time of operation and unit of output is important. Of two mixers able to turn out the same perfectly mixed product and each having the same capacity per batch, the first

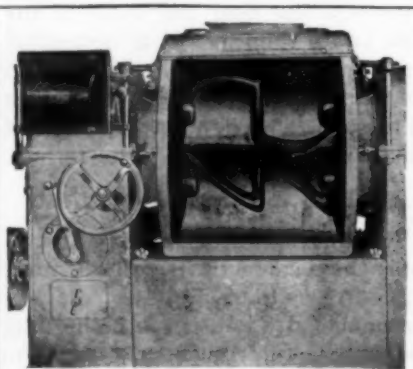
may consume twice as much power as the second, but if it does its work in less than half the time, it is the cheaper mixer to operate. While on this point it is interesting to note that it is not always easy to judge just when a mixture is ready to be discharged, and there are numerous cases of mixers being operated longer than necessary, as there are also some where longer mixing periods would be desirable.

Other points to be considered when selecting a mixer are the mechanical features, such as the methods of loading and discharging, the driving and reversing of the rotating members, the tightness of joints and bearings against leakage and against grease contaminating the materials being mixed, the adequacy of steam or brine jackets, protection against dust or fumes, and such other special features as may be required to meet conditions.

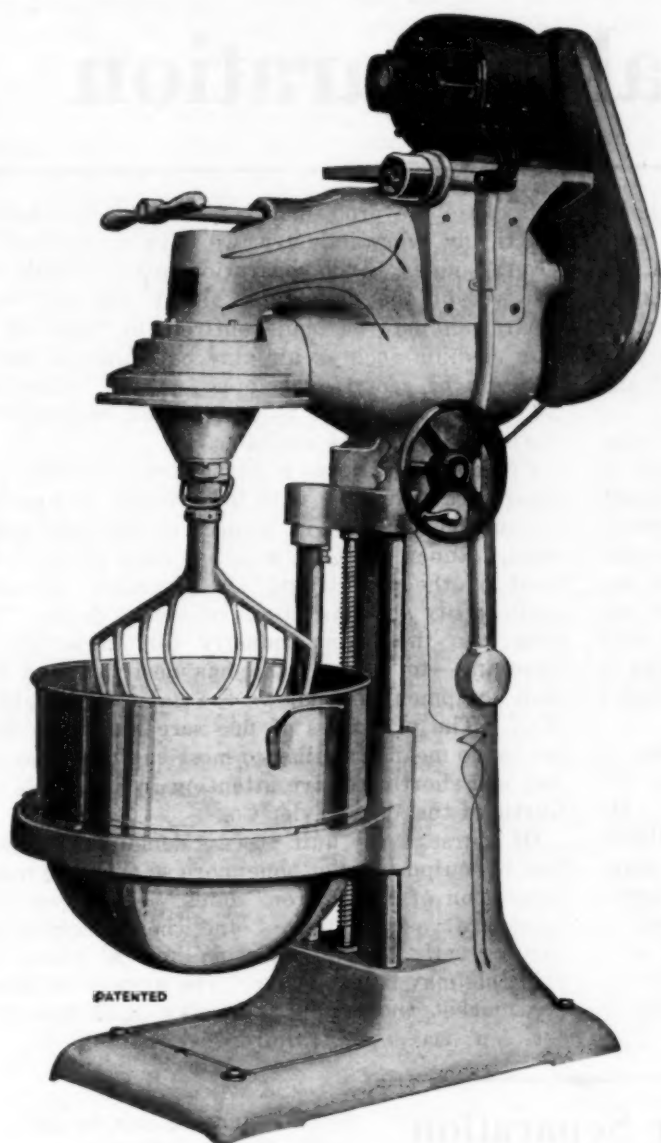
A word of advice to prospective purchasers would not be inappropriate at this point: Tell the manufacturers in full detail about the nature of the materials to be mixed, and the nature of the finished product desired. They are specialists in mixing processes and know from experience how to get the best results. If your problem is a new one not covered by their experience, get them to co-operate with you in experiments until the problem is solved. Doubtless there are mixers in use, giving inferior results, because the manufacturers never intended them for the work they are doing.

HOW MIXER DESIGN DEVELOPED

The combination of both mixing and kneading action is best illustrated by that type of machine consisting of a rectangular vessel or trough in which are placed horizontally two parallel mixing arms or blades which rotate toward each other at different rates of speed. The bottom of the trough is curved and divided longitudinally to form two half cylinders which are swept by the blades, while the saddle formed by the junction of the two half cylinders serves to divide the mass being worked so that it is passed back and forth from one blade to the other. This type of mixing and kneading machine had its origin in the patents of Paul Freyburger in 1876 and the later modifications of Paul Pfeleiderer in 1882 and 1895. The basic principles involved in its construction are the shape of the



TWO-BLADE MIXING AND KNEADING MACHINE



SPECIAL TYPE OF MIXING AND KNEADING MACHINE

trough, with particular reference to the ratio between its length and width, and the peculiar shape and proportions of the blades.

The original blades consisted of two elliptical disks set obliquely to their axes of rotation and describing with their perimeters two parallel cylinders concentric with the half cylinders formed by the bottom of the trough. In the words of Freyburger's patent, "These elliptical blades or disks, by revolving, have their flat cutting or dividing edges caused to approach and recede in such a manner as to cut, divide, disintegrate, stir, mix, throw, squeeze and knead the material, dropped onto them from the open top of the trough." Both the front and back surfaces of the blades exert pressure on the materials and every plane from top to bottom of the mass is

cut by the blades, so that materials of heavier specific gravity cannot collect at the bottom and those of lighter at the top of the mass, but the whole is intimately mixed.

Pfleiderer discovered that the pressure exerted by these disk blades through the material against the trough could be diminished, the driving power requirements lowered, and the mixing and kneading action at the same time improved by cutting out two sectors (or leaving gaps) in the perimeters of the blades. On this principle are based many of the various mixing blades seen on the market today.

One defect of the simple disk blade is that it does not sweep the corners and a large part of the trough ends, and therefore leaves a small portion of the mass unacted upon. To remedy this a scraper was attached to

the blade shaft at each end. Later, radial arms forming part of the blade as a whole supplanted the scrapers and the blades were constructed to sweep every point on the trough so that no particle of material can escape the mixing and kneading action. By the prospective purchaser of a mixing machine, this point merits careful consideration, for unless the mixer is so constructed it cannot mix perfectly.

HOW MIXERS ARE DISCHARGED

The chief mechanical problem, after the mixing action proper, involved in this style of mixer is the method of discharging the mass from the trough. Two types of discharge have been evolved, the first being effected by tilting the trough, the second by means of various outlets placed in the bottom of the trough, one for each of the two half cylinders. In mixers with but a single shaft, the tilting of the trough is a comparatively simple problem, as the shaft, being centrally located, is coincident with the center of gravity, and serves as a natural tilting axis. In mixers with two blades, the front blade shaft may serve as the tilting axis, if the drive shaft is below the blade shafts; or, if the trough is set closer to the floor level and the drive shaft is in front of the blade shafts, the drive shaft affords a tilting axis. In both these cases, but more so in the latter, the weight of the trough and its contents must be lifted by the tilting mechanism.

On mixers that are too large to be tilted by hand the type of mechanism in most general use consists of a large square-threaded screw connected to the trough by a nut, the screw being actuated by a set of mitre gears which in turn are connected by suitable means to the main drive shaft. Other tilting methods have been developed, based on hydraulic and pneumatic principles. The discharging of the mass when the trough is tilted is facilitated by the rotation of the blades, especially in the reverse direction from that used during mixing.

One of the outstanding characteristics of the style of mixer and kneader above described is its adaptability to a very wide range of uses. While obviously being able to mix together liquids or dry materials, it is essentially designed for handling plastic masses where a kneading in addition to a mixing action is required.



Mechanical Separation

OUR great trouble in dealing with the purchaser of separating equipment is to find out what he wants to do. If we can sell him the idea of checking up his operation through testing sieves and tonnage measurements, we have faith in his success. Thus writes one large manufacturer of a type of apparatus that is perhaps most widely used of any in the chemical engineering industries.

A production man who considers the problem of separating solids from solids too simple and inexpensive to deserve serious attention is making a serious though not infrequent mistake. In the first place, the process is often a difficult one demanding the utmost ingenuity for solution. Again, much of the apparatus in use today is either unnecessarily crude or altogether unsuited to the problem in hand. Labor and power costs are consequently unnecessarily high. Minor savings in the operation of a given unit may result in a significant total.

Suppose the production engineer of a given plant is called in to discuss a change of process involving the grading of material according to size and kind. He has the choice of a rotary screen, a flat screen, a vibrating screen, a Wilfley table, a centrifugal air or a magnetic separator. Unless he has had previous experience in dealing with the particular problem in hand he is not unlikely to make a decision that he will later regret. In the event that he reserves judgment, intending to look the matter up, we predict a tough session in the library.

Because the problem is a broad one dovetailing into practically every industry, we have approached it from several angles. Such separations may be made in either the wet or the dry state. If in the dry state, the separation may be made entirely by force of gravity or a medium such as air may be employed for the application of centrifugal force. Again, wherever iron-bearing materials are to be removed, magnetic or electrostatic devices are available.

Prof. C. E. Locke, a consulting engineer of broad experience in dealing with the problem, has outlined the various possibilities in respect to methods and equipment. Rubert M. Gay, who has done much in development of the centrifugal air separator, discusses the applicability and limitations of such a device. We have gone into the paper industry for an article on wet screening—to a man who has designed and installed such equipment and knows the game thoroughly, R. B. Wolf. The principles of fine screening in a dry state are by no means familiar to most engineers, so this subject will shortly receive attention in an article by F. S. Curtis of the W. S. Tyler Co.

Of course, every unit process demands detailed attention to equipment, but none more so than the mechanical separation of solids from solids. The types of equipment are vastly different and the principles involved vary greatly. A predilection for a given type or principle may be expensive. The answer is, Investigate the market thoroughly. It may spell the difference between success and failure.

Principles and Practice for Separation of Solids From One Another

BY CHARLES E. LOCKE

Professor, Department of Mining Engineering and Metallurgy, Massachusetts Institute of Technology, Cambridge, Mass.

THE chemical engineer has perhaps to deal more with solid from liquid separations than with solid from solid separations, but a moment's thought reveals that we all have to make separations of solids alone, from the lowest savage who employs visible properties in selecting that which is good for his food or clothing from that which is valueless or even harmful, up to the technical man who has the command of many physical properties to enable him to produce delicate divisions of solid materials.

However, whether the separation be simple or difficult, it will be found to be based either on difference in size or on difference in kind. Frequently differences in both size and kind are available.

One does not realize the extent to which sizing is employed in preparing many of the common materials of everyday life. If one goes to the market one finds that oranges, melons, prunes and many other products are graded according to size. If one buys coffee, sugar or spices, these may be coarse or fine. If it be chemical supplies, powder and such like, they may be in lump, granulated or pulverized form. At the hardware store, abrasives and abrasive papers are offered in a choice of sizes. Many commercial products, such as flour, pigments, talc, cement, clays, polishes, etc., are not marketable unless they are up to a certain standard of fineness, with coarse and gritty matter removed. Pulverized coal, which has come into

such extensive use in recent years, calls for a reduction to a certain fineness. Cereals and seeds are carefully prepared by sizing. And so one could go on with many more examples of the extensive use of grading by size to prepare many of the useful articles which we all consume.

Coming to separation by kind, the applications are more numerous. In the grain industry simple beating separates the cereal grains or abrasion takes corn from the cob. A combination of sifting and air blowing purifies the grain by removing dirt, chaff, immature grains, weed seeds, etc. The removal of hulls, the polishing of rice, the extraction of seeds from cotton and many other similar operations call for various forms of machines. Dry concentrating tables, something like those used in ore dressing, have been used for separating grains and seeds from dirt and impurities.

Ore dressing and coal washing, from the viewpoint of tonnages



treated, represent the largest field of solid separations. The two mills of the Utah Copper Co. alone have a capacity of 40,000 tons of copper ore per day. Mechanical methods are employed exclusively in such plants. The problem varies from the recovery of a single valuable mineral from waste to the separation of two or more minerals, such as those of copper, lead and zinc, from one another and from waste. Wide conditions prevail, from coal and iron, where the valuable portion may be 75 per cent or more of the material mined, up to diamond recovery, where hundreds of thousands of pounds of diamondiferous ore yield only 1 lb. of diamonds. If mechanical concentration were not available and we were forced to rely on other processes, the cost of extracting many products from their ores would be much higher and the price of the products themselves would be correspondingly increased.

METHODS OF MECHANICAL SEPARATION

Having considered the application of solid separations, it will be of interest to summarize the physical properties on which the separations are based and the principles of the apparatus used.

Sizing is accomplished wet or dry in a multitude of sifting devices, choosing whichever may be best suited to the special problem in hand. Recent developments in screening apparatus are vibrating screens of the Mitchell and Hummer types. The screening surface is vibrated at a very high rate, which makes for an efficient screening available for a wide range of materials.

Besides by use of screens, separation of fine material is made by air or water. Horizontal currents of either will carry along fine particles and leave coarse particles behind. Similarly vertical rising currents of air or water will lift fine particles while coarse particles fall. Apparatus of this type is represented by air separators, such as the Gayco-Emerick, used in the preparation of pulverized coal and in the separation of fine talc, feldspar, etc., and hydraulic classifiers, used in ore dressing. Strictly speaking, grading by air or water is not true sizing unless the material is homogeneous and of uniform shape, since a small particle of high specific gravity has the same settling rate as a larger particle of low specific gravity. Flat

and elongated particles have a slower settling rate than rounded or cubical particles of the same size.

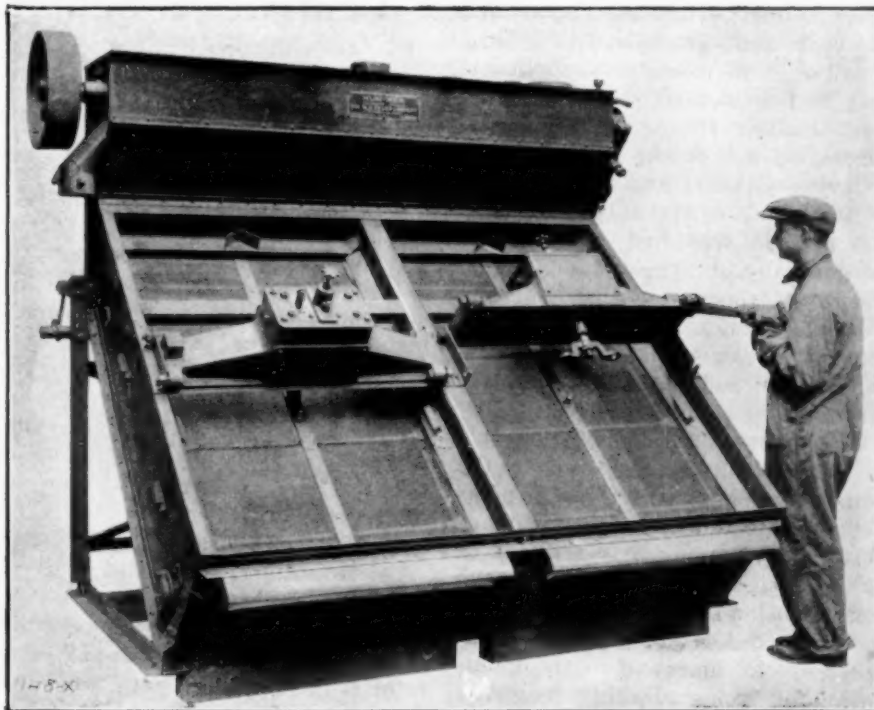
The most important physical property, at least for the separation of ores, is that of specific gravity. The same principles underlie separations in the more distinctly chemical engineering fields. Most frequently the separation is made in water, although under certain conditions one is forced to use air as the settling medium; but the basic principles for air and water are the same and the forms of apparatus used are very similar. Horizontal and vertical currents of air or water have been already referred to under sizing. Subjecting a mass of material on a screen to successive vertical pulsations, alternating perhaps with suction, of air or water, will create a mobile mass in which the heavier material will stratify beneath the lighter. This is the principle of the jig, in which either the ore may be jigged up and down in the water or the water may be moved through the ore.

Many forms of tables have been used. The simplest is an inclined surface on which the solid material is fed with water at the top. Heavy material will not be washed down the incline as fast as light material. Considerable sizing occurs here, since large particles offer more surface to the water film and are carried down faster than smaller particles. Other tables have a bed of pulp or

solid and water on a moving table top or belt, usually inclined. A shaking or jerking motion keeps the pulp mobile so that stratification can take place and by the action of a film of wash water, combined with the travel of the belt or the jerk of the table top, the light upper stratum is washed off at one point of the table while the lower heavier stratum is carried by the belt or jerked to another point. The table most used today is the jerking table of the Wilfley type, which is operated wet. A dry table on much the same principle is the Sutton, Steele & Steele, which obtains stratification by means of blasts of air up through the porous table top of cloth.

SELECTION BY GRAVITY IN SUSPENSION

Solutions of high specific gravity have been used for delicate separations in laboratory and analytical work, a solution being chosen of intermediate gravity such that one substance will sink and the other float. Zinc chloride solution will separate coal from slate in this way. More recently very successful commercial application on coal has been made by the Chance process, but instead of using a solution of a salt, a mixture of sea sand and water in continual agitation forms a quicksand pulp which possesses the same properties of separation as a heavy liquid. Thus a mixture of 2 parts of sand of 2.6 specific gravity with 1

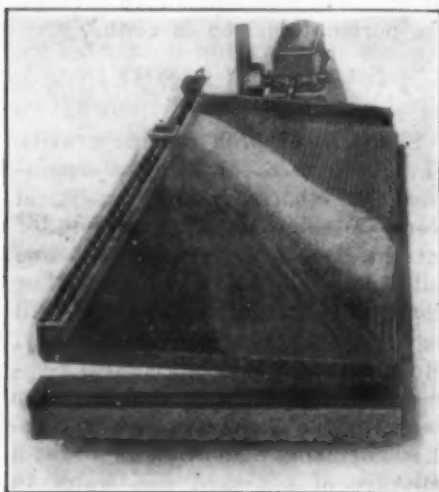


INCLINED VIBRATING SCREEN



part water makes a pulp of 2.07 specific gravity, on which anything lighter than 2.07 specific gravity will float.

A remarkable property that has found rapid growth in application to ores during the last decade is that on which flotation is based. This property causes certain substances, especially mineral sulphides, to attach themselves to air or gas bubbles and to resist wetting by water while other minerals of the oxide class are easily wetted. By the use of suitable reagents to reduce the surface tension of the liquid and by suitable apparatus to bring the solids in con-



WILFLEY TABLE

tact with air or air bubbles, the sulphides float on the liquid as a scum or froth while the gangue particles sink. Certain metals, as well as coal and graphite, also float readily. The process is applicable only to fine material below 50-mesh size, or about $\frac{1}{4}$ mm. Hardly a concentration mill in the United States today is without flotation as a part of its plant, whereas 10 years ago the process was just starting experimentally. The fundamental theory of the process is not fully worked out, but it involves surface tension phenomena, adsorption, capillarity and probably electrostatics.

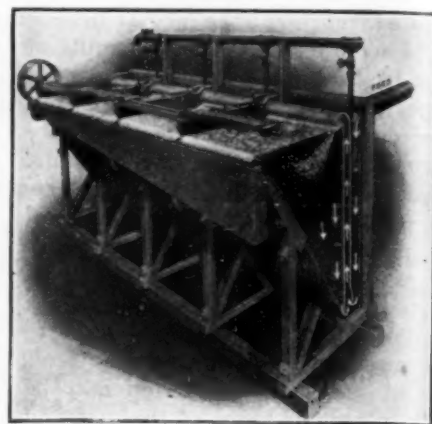
Magnetism is a property applicable to magnetic materials even to the point of employing high power magnets on substances so weakly magnetic as to be commonly thought of as non-magnetic. Aside from the concentration of iron ores, this process finds considerable application on other special ores and in the elimination of iron and other magnetic impurities, as in foundry sand, ground products, paper pulp, etc. By

mixing the material with water, a separation of fine material may be made. Some materials, such as pyrite, not naturally magnetic, may be rendered so by a reducing roast and then separated from non-magnetic material.

Although associated by some with magnetism, electrostatic separation is a distinct process based on the relative conductivity of substances which determines the speed with which they take on a static charge. In contact with a charged electrode, particles of one kind take a charge quickly and are repelled and separated from substances of poorer conductivity. Delicate separations may be made, since only a small difference in the relative conductivity of two substances is needed. Materials must be absolutely dry and the process is not applicable to very coarse or very fine particles.

Heating may affect the properties of substances so as to make a separation possible. Some ores decrepitate and fly to pieces on heating and can be screened away from others which do not decrepitate. Heating makes some ores porous and has the effect of changing the acting specific gravity. Heating for magnetism has been already mentioned.

Hardness or friability is occasionally a basis of separation, where by gentle agitation one substance which is soft can be reduced to a fine state



HYDRAULIC CLASSIFIER

of division and then separated from a less friable substance by screening.

The shape of particles may effect a separation. For example, if coal which is rounded and slate which is flat are run down an incline, the coal rolls while the slate slides and the added momentum of the coal carries it away from the slate. If ores of mica or molybdenite are crushed in rolls and screened, the oversize will consist of practically clean mica or molybdenite and the gangue will be in the undersize.

Centrifugal separation, which is based on specific gravity, which has been used so successfully on liquid-solid separations, has not been developed to solid-solid separations, although inventors promise to solve this problem in the near future.

Centrifugal Separation of Solids From Solids in Air

An Ingenious Application of a Simple Principle to Separations According to Size—Applies to Many Processes

BY RUBERT M. GAY

President Rubert M. Gay Co., New York City

IN ALMOST every plant there is frequent necessity for separating materials according to size. A screen installation of one sort or another is often the most practicable apparatus for carrying out the required operation. There are certain materials, however, such as abrasives, caustic, slightly damp materials of various sorts, etc., which can be screened only with considerable difficulty and expense both in operation and in upkeep.

It not infrequently happens in such cases that a centrifugal separator is the feasible device for doing the trick. The same type of apparatus is fairly widely used in con-

nection with crushing and grinding operations for the purpose of removing the fines, thus doing away with the cushioning effect of such material in the grinding mill.

Air separators of various types have been manufactured and used for a great many years; in fact, the Biblical reference to the winnowing of the chaff from the wheat describes air separation as it is commonly known; the principle being that a current of air will carry light material to a greater distance or greater height than it will heavier material, and all air separation is based on this principle.

In some cases it takes the form of



a long passage into which the material is blown, the heavier particles falling closer to the inlet, while the lighter ones are carried farther down the passage. Sometimes baffles are interposed to make a change in the direction of the air current, where the material is very light and it is not practicable to extend the passage beyond a certain length.

In other separators the material is spread by a revolving distributing plate in the form of an annular curtain through which a current of air is forced or drawn, the velocity of the current being regulated to take up particles of the desired fineness, while the heavier ones fall by gravity. Provision is made for collecting the fine and coarse particles and discharging them through convenient spouts. The Pfeiffer, Emerick and other separators copied from these are of this type.

Still another form of air separator is the cyclone, commonly used for extracting dust from the air. Many arrangements have been tried to regulate the velocity of air and the

distribution of material. All of these devices depend on the velocity of the air current and when this is generated by means of a blower or fan any variation in the speed of the apparatus varies the product; on the other hand, the adjustment of the fineness of product is obtained by varying the speed of the blower or fan.

Separators of the above types have been used with more or less success for a great many years, but at the present time the demand is for closer sizing and finer materials which cannot be produced on velocity separators, and it is for this purpose that the device here described was designed. While this machine is called an air separator to distinguish it from screen separators, the actual sizing of materials is made by centrifugal force, generated by mechanical means. As this centrifugal force can be adjusted through a very great range, it is possible to obtain either coarse or fine products, the range of the separator being from about 80 mesh to 350 mesh and finer. Products as fine as 99½ per cent through

325 mesh are easily obtained in regular practice.

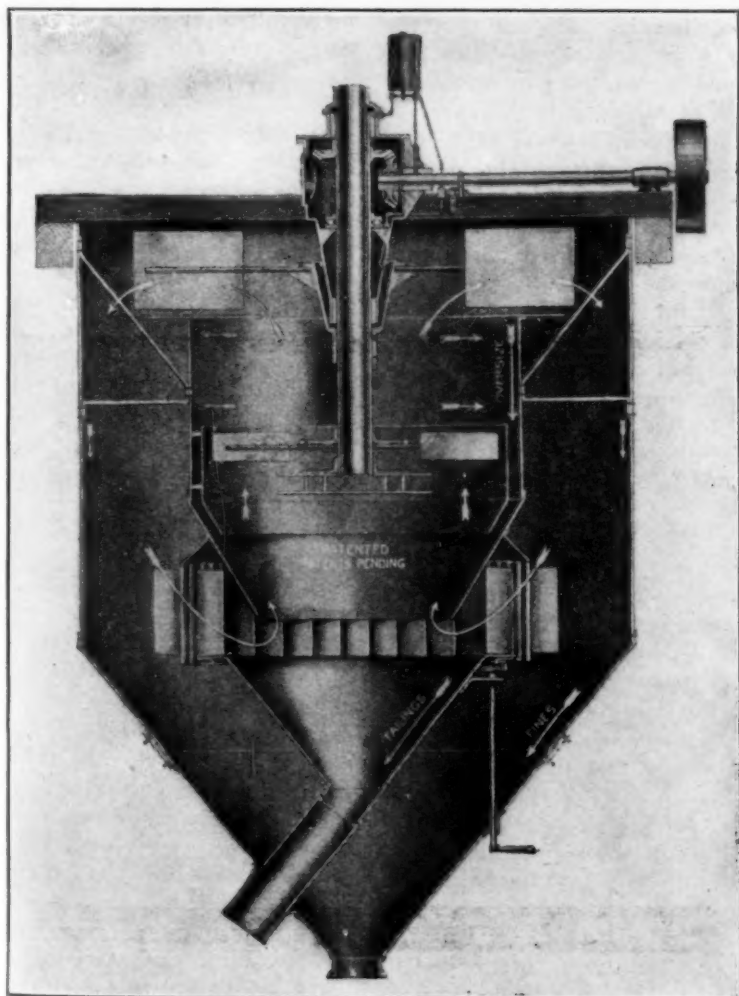
As the main fan and the centrifugal fan maintain the same relative action, variations in the speed of the separator have no appreciable effect on the fineness of the product; consequently when the machine is once adjusted for a given fineness the product remains constant at all times.

This separator has in a way revolutionized fine separation and has made possible the commercial production of materials which formerly could be made in only small quantities by laboratory apparatus at very high expense. It has also made possible the utilization of many waste products, such as slate dust, which can now be reduced to meshes fine enough for paint filler and similar purposes; clays and marls for rubber filler are easily separated to 300 mesh and finer, as well as various paint materials, talc, etc.

In the spar field several grinders are abandoning their old-fashioned dump cylinders and are installing continuous feed tube mills in closed circuit with separators of this kind, thereby reducing the cost of grinding and maintaining a uniform product, which they can sell at a guaranteed screen analysis. In cement plants these separators maintain a uniformly fine product at all times and obviate the necessity of constantly testing the product and adjusting the feed to the grinding mills.

The workings of a typical centrifugal air separator may be apparent from the accompanying cut. The shaft is hollow and carries at the bottom a distributing plate, above that a fan and at the top, just under the cover, centrifugal vanes for maintaining the necessary circulation of the material in the air medium.

Material is fed into the stationary feed pipe and falling on the revolving distributing plate is thrown off in a thin sheet. The main or lifting fan carries all but the coarsest particles up into the centrifugal separating chamber, where the dust-laden air is caused to rotate by means of the centrifugal vanes. This positive mechanical rotation generates a uniform centrifugal force throughout the ascending column of air. As the centrifugal force acts on the particles in direct proportion to their weight, the heavier ones reach the outside more quickly than the lighter ones and are thrown out



CROSS-SECTION OF CENTRIFUGAL SEPARATOR



of the ascending column of air before it reaches the opening into the fan chamber. The light particles remain in the air current and are carried into the fan chamber.

The heavier particles slide down the inner wall of the separating chamber, back of the skirt surrounding the distributing plate and falling off the lower edge of the separating chamber, pass through the incoming air and are discharged through the spout in the bottom of the tailings cone.

The main fan discharges the air, carrying the smaller particles in suspension into the outer casing or settling chamber, imparting a rotary

or cyclonic action which throws the suspended material against the outer wall, down which it slides to the outlet opening in the bottom of the separator. The air, freed of most of the dust, returns through the space between the separating chamber and tailings cone, passing around and through deflectors and baffles, which remove the dust remaining in the air.

Moderate changes in fineness are made while the machine is in operation by means of the adjustable deflectors which act as a damper to retard the speed of the circulating air but which do not vary the centrifugal force.

screens, the tailings being conducted into a lesser number of similar screens for rescreening and very often into a third set, or final tailings screen.

There are at the present time on the market a number of types of centrifugal screens, the later ones being horizontal instead of vertical, thus simplifying the drive. These centrifugal screens are used mostly for screening short-fibered material, such as ground pulp and soda pulp cooked from hardwoods.

When these screens were first put on the market they were used to a certain extent for screening sulphite and sulphate pulps, cooked from coniferous woods. Generally speaking, however, it has been found best to screen these long-fibered pulps on flat screens, as the power consumption per ton of pulp is less and a greater percentage of dirt is removed, for the obvious reason that to screen long-fibered stock through a round hole the diameter of the hole must be too large to remove the dirt effectively. If a small diameter hole is used with the long-fibered stock, the capacity of the screens is very materially decreased and the percentage of rejections is too high.

THE ROTARY SCREEN

In recent years, a type of screen known as the rotary screen, a revolving screen, has come onto the market. This screen uses copper slotted plates, similar to those used in flat screens. The plates are usually fastened to a cylinder, which revolves slowly in a vat containing stock. The discharge is from the outside of the cylinder to the inside, the purpose of revolving the plates being to give them a continuous washing with a shower located on the top of the cylinder.

These screens are usually three-quarters submerged and the stock level on the inside of the screen is nearly as high as the stock level on the outside.

The screening action is brought about usually by means of a cam, or crank motion, which oscillates the wall of the vat, thereby causing the stock to be forced alternately toward the plate and away from it. In some types of rotary screens this forcing of the stock against the plates is accomplished by means of a broad submerged paddle, which causes a movement of the stock against the plate, the vat in this case remaining stationary.

Pulp Screening—Solids From Solids Separation in Solution

BY ROBERT B. WOLF

President, R. B. Wolf Co., New York City

THE fabrication of a pulp for paper making generally demands that hard bundles of fiber, metallic particles, knots and extraneous matter of all kinds be eliminated. To this end a special technique has grown up in the pulp mill, that of separating solids from solids in suspension. To carry out this operation efficiently and economically, screens of various types have been devised.

The first type of screen used in the paper industry was known as the shaker type. This screen consisted of a horizontal tray in the bottom of which were fastened a number of bronze plates. These plates were slotted on about $\frac{1}{4}$ in. centers, the slots being about 0.016 in. wide and about 4 to 5 in. in length.

The pulp was conducted to this tray by means of a spout, the consistency of the pulp being about 1.0 per cent. The screened fiber passed through the slots to a receptacle below the tray, the screened out particles remaining above the plates, where they were scraped off and removed at intervals. In order to prevent plugging up of the slots, a jarring motion was given to the tray, by means of cams at the corners of the trays.

The next type coming into general use was what is known as the diaphragm or flat screen. This screen, in general appearance, is very much like the shaker screen, the fundamental difference, however, being that this screen depends upon a suction, created by means of a closed

chamber below the plates, the tray being stationary. At the bottom of this closed chamber is a series of diaphragms actuated by cams resting on a shaft directly beneath. The shape of the cams is such that the upward throw is more rapid than the downward, or suction throw. With this type of screen it is necessary to keep the space between the diaphragm and the plates completely filled with pulp solution. In other words, to insure proper screening, no air should be allowed to accumulate under the plates.

The advantage this type of screen has over the shaker type (now obsolete) is that because of its more positive action finer slots can be used in the bronze screen plates. The width of these slots usually ranges from 0.008 to 0.012 in. in width.

VERTICAL TYPE CAME FIRST

The first centrifugal screen in common use was the vertical type. The scheme upon which this screen operates depends upon the use of a vertical impeller, or fan, which throws the pulp against a vertical cylinder, made of copper and perforated with round holes from 0.060 to 0.080 in. in diameter. The screened pulp is driven by the impeller through the screen plates and collects on the outside, the unscreened pulp dropping down on the inside of the plates into what is known as a tailings spout.

Usually the stock to be screened is conducted to a battery of these



The rotary screen is used largely on paper machines and very little for screening pulp. It is quiet and requires a relatively small amount of power.

Preceding the screening system in pulp mills devices known as knotters are generally used. These knotters have coarse plates and remove the larger shives and coarse particles, the purpose being to increase the capacity of the regular screens. The plates in the knotters are usually perforated with round openings varying from $\frac{1}{8}$ to $\frac{3}{4}$ in. in diameter. These knotters are usually slow moving cylinders, on the inside of which the stock is fed. The screened stock passes through the plates and the re-

jected stock is conducted to the end of the knotted cylinder, where it is discharged into a refining system, to be ground up into a material which has been found to be suitable for coarse paper.

The three types of screens used at the present time are the diaphragm, or flat screen, the centrifugal and the rotary. The first type is used largely in sulphite and sulphate mills, where long-fibered stock is to be screened, and on the end of the paper machines for removing dirt just before the stock passes on to it. Centrifugal screens are used especially for screening short-fibered stock, such as groundwood, or soda pulp.

clay used in making china often carries small particles of iron whose presence in the product gives a blue coloration. This is removed in the type of machine which handles suspensions, shown in Fig. 2. Likewise in abrasives, unless the iron compounds are removed, blue colorations will appear, indicating mechanical weakness. In foundries the magnetic separator finds application as shown in Fig. 1 in reclaiming sand. Here the separator is shown acting in series with a trommel.

A very interesting application of this method of separation has re-

Putting Electricity to Work

In Plants Where Cutting, Crushing or Grinding Are Used in Processing Material Magnetic Separation Is Often Advisable

ORIGINALLY the process of magnetic separation was used largely for the removal of tramp iron from material to be disintegrated. In this way expensive equipment was safeguarded and continuous production fairly well insured as far as breakdowns due to attempting to crush bolts, shear horseshoes, etc., were concerned. Iron and iron compounds, however, because of undesirable properties which they impart to such manufactures as ceramic wares, abrasives, cellulose products, soaps, etc., are frequently a nuisance.

In theory there are four types of magnetic separations that are possible. Deflection while falling through the air, the old Edison principle, is not used except in electrostatic apparatus as mentioned in the article

by Prof. C. E. Locke. Adhesion to a moving magnet, temporarily made powerful by induction, is the principle made use of in separating steel scrap from brass. Running the iron-bearing material in a suspended state over a submerged magnetic system is used in freeing clays, paper pulp, etc., from the iron. By far the most common type of separator is the so-called pulley type, in which the separation is made directly on a belt conveyor by means of a magnetized pulley at one end.

Iron usually found with glass cullet when entering the furnace in the batch always discolors the molten glass. The one remedy is to remove the trouble at its source. Fig. 3 shows a separator operating in a plant of the Owens Bottle Co. The

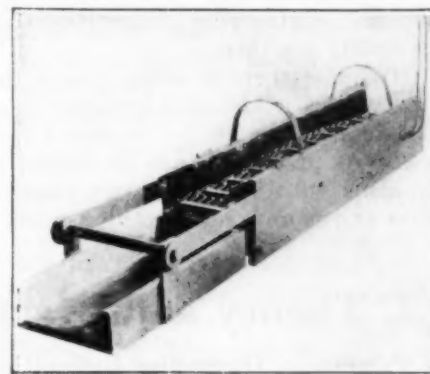


FIG. 2—MAGNETIC SEPARATOR USED ON SOLIDS IN SUSPENSION

cently been announced in the concentrating of clover seed. Because of the great likeness of clover and dodder in shape and size, and because dodder is a great nuisance, a difficult separation problem arose which apparently had no solution. The idea was conceived of wetting the mixed seed and allowing the mucilaginous excretion of the dodder to pick up iron particles which were next mixed with the seed. When dry the combination is separated magnetically, making a clean cut.

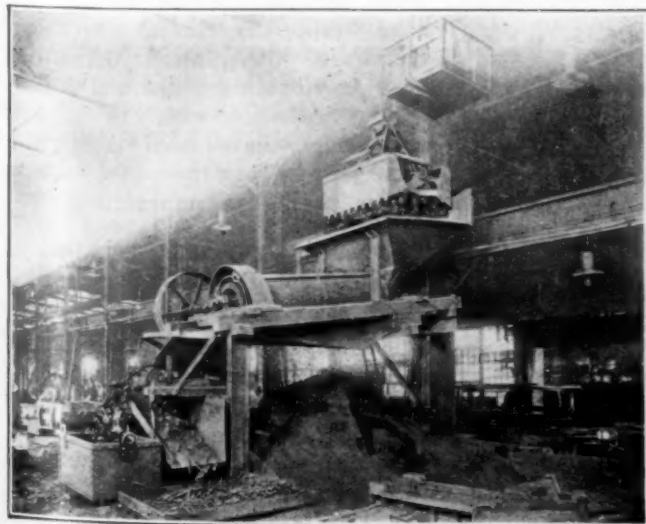


FIG. 1—TREATING FOUNDRY SAND FOR REMOVAL OF TRAMP

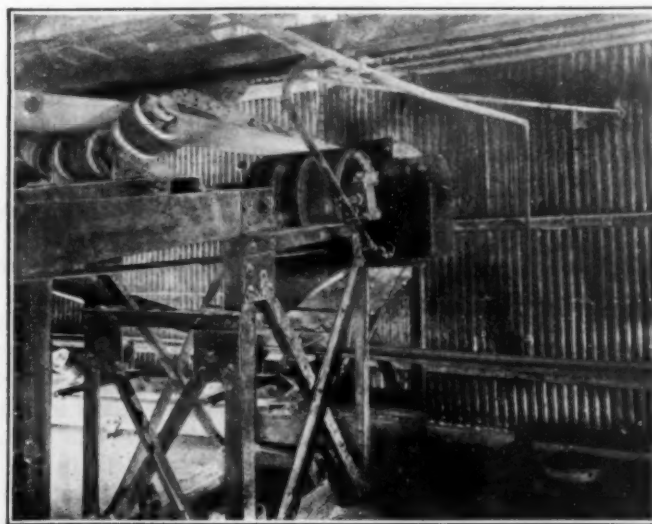


FIG. 3—IN PLANT OF OWENS BOTTLE CO. HANDLING GLASS CULLET



Thickening

NOT very many years ago the average production man in the chemical engineering industries had heard of thickening only if he had contact with his mining friends in the West. It was a grand old process for the mining engineer in concentrating his slimes so that they could be filtered without pumping an impossibly large quantity of water through the filter. For years it was used successfully in the "great open spaces" before the chemical engineering industries thought of it as a possibility for them.

Of course there is some reason for this, since comparatively few chemical processes used water in quantities large enough to require an enormous filtering area. As production has increased, however, and quality along with production, the ease of filtration became more and more a significant economic problem. It has

been found distinctly easier to filter a precipitate that has been through a thickening process, as it has had an opportunity to agglomerate, and the proportion of difficultly filtrable material is thereby diminished. There is also a vast difference in the purity of the cake that can be obtained if the material has been run through a battery of thickeners which amount in reality to a continuous counter-current washing system.

The converse of this process is the clarification of liquor from difficultly filtrable materials. Here thickeners are being used with great success. Still another use of this process is in efficient leaching of a soluble solid from slag or ash. Obviously, the tremendous developments are beyond the scope of a single article and we have asked Mr. Tyler to confine his attention to the principles that lie back of the process and to the most significant difficulties in operation.

Theory and Practice of Thickening

Principles, Operating Difficulties and Equipment for Industrial Settling Problems Are Considered So as to Bring Out the Essential Factors

BY CLIFFORD H. TYLER

The Dorr Co., New York

IT WOULD BE difficult to estimate the number of chemical and metallurgical processes which, in one step or another, involve a suspension of solids in liquids. They may range all the way from a few fine particles affecting the absolute purity of water through colloidal and heavier suspensions, to thick ore slimes and cement slurries. Detailed study of the behavior of this class of materials is becoming more and more important in the economical control of many operations.

Thickening, or "settling," while only one of the phenomena of suspensions, probably finds wider application than any other. The value to be derived may be either in de-watering the residue or in clarifying the supernatant liquid, or both. The difference in purpose, however, may change the way in which a given problem is handled.

It will be well, before attempting a general discussion of theory and practice of thickening, to emphasize the fact that, while materials may be classed in types, according to thickening behavior, still each specific substance presents an individual problem and must be studied

as such for intelligent handling. We shall see, also, that ingenious methods of treatment may greatly vary the settling habits of any suspension.

GENERAL THEORY

It is generally accepted that most settleable suspensions separate into sludge and clear liquid in several stages, best explained by means of the diagram shown in Fig. 1. (See H. S. Coe and G. H. Clevenger, *Trans. A.I.M.E.*, vol. 55, p. 356, September, 1916.)

No. 1 shows a suspension as fed to a thickener, thoroughly mixed. Heavy particles, if present, will settle immediately, as shown by the dark bottom layer in the following cylinders. The rest of the pulp soon shows four more or less distinct layers, or zones. Zone *B*, of the original consistency, seems to fall away from the surface, leaving the clear liquid *A*. Zone *D* is a layer of particles which, having settled, rest directly one upon the other, with liquid still in the interstitial spaces. Zone *C* is a transitional layer the consistency of which varies from that of *B* to that of *D*.

Obviously, zones *B* and *C* will grow gradually smaller and finally disappear, leaving *A* and *D*, separated by a line called the critical point. This marks the end of free settling and the start of compression. That is, the particles resting on one another can go no further by mere settling, and any increase in density must come by the upward passage of water through spaces or channels in *D*, in some way provided. This final step is very important in controlling the percentage of moisture in the final sludge.

Slow stirring or working of this settled pulp has been found to give a much denser product in less time than unaided compression. This raking seems to squeeze out the water and facilitate its upward passage, especially in a continuous thickener. Other means of control, such as vibrating tanks and quivering vertical wires which extend into the sludge, have been tried with some success, but the added expense makes their use impractical.

SPEED OF SETTLING DEPENDENT UPON PARTICLE SIZE

It is evident that speed of settling will depend largely, other conditions being the same, upon the size of the particles. From this standpoint, the classification of dispersed systems by Ostwald is useful. It consists of three classes as follows:

1. Coarse dispersions or suspensions, in which the particles are



greater than 0.0001 mm. in diameter. These will usually settle according to the general theory described above.

2. Colloidal solutions, with particles from 0.0001 mm. (or 0.1 micron) to 0.000001 mm. (or 1 millimicron) in diameter. These will be discussed presently.

3. Molecular or true solutions, with particles smaller than 1 millimicron. The presence of these particles cannot be detected by physical means and, of course, they are not subject to thickening.

By far the greatest difficulty encountered in thickening research has been in connection with colloids. Where colloidal material, even in small amounts, is present, its treatment constitutes practically the entire problem, especially if a clear overflow liquid is desired. Sizes, rates and methods designed to handle the colloids will usually be more than sufficient to take care of the coarser material. A glance, therefore, into that broad and important branch of physical chemistry is necessary to present this phase of thickening. (See also Willard A. Deane, *Trans. Amer. Electrochem. Soc.*, 1920, vol. 37, p. 71.)

COMPLICATIONS INTRODUCED BY COLLOIDS

A colloidal "solution" is stable—that is, it will not settle—when the particles are so fine that their intrinsic, zigzag motion, called the Brownian movement, is sufficient to keep them dispersed despite the downward pull of gravity. Their behavior in this respect is not unlike molecules of a gas in a container, bombarding one another and the walls at a rapid rate.

When a material is in this very fine state of subdivision, it will be readily seen that the total surface of the particles is enormous compared to their actual mass. This amplifies the importance of adsorption, or surface energy of the particles, and as a

result of this, it is assumed each particle carries an electric charge, whose sign depends on the specific material. If the particles are all similarly charged, they will repel one another and help, if not cause, the Brownian movement.

It follows, therefore, that to settle a colloid we must neutralize the charge on the particle, after which the solids will cohere and become a coarse suspension. This flocculation may be brought about in several ways.

First, it is necessary to determine the sign of the charge, and this may be accomplished by cataphoresis. A current is passed through the solution and the particles will migrate to the anode or cathode according to their negative or positive sign. In practice, however, it is more common to add a colloid of known sign and note the behavior of the solution.

Having determined the charge, ions of opposite sign may be introduced by adding an electrolyte, a colloid of opposite sign, or a mixture of the two. The amount to be added in each case is important and varies according to the concentration of the colloid, valency of the precipitating ion, and presence of "protective" colloids, such as oils, soaps, etc., which tend to prevent flocculation. Often much experimental work is necessary to determine the most economical and efficient agent to add. The colloid of opposite sign may be added directly or be produced in the solution by chemical precipitation. When both colloid and electrolyte are used, the action is similar to that of alum in water purification. The electrolyte flocculates the colloid added, the flocs formed serve as nuclei to which the original particles adhere, and the whole, settling, strains out all suspended material.

Passing an electric current through a colloid to flocculate it has been tried with some success. Soluble

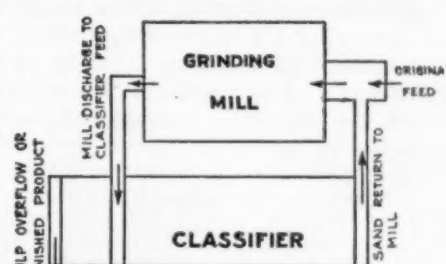


FIG. 2—PREVENTING FORMATION OF COLLOIDS DURING GRINDING

electrodes are used, introducing charged ions into the solution and so neutralizing the colloid much the same as an electrolyte. Certain bacterial growths, such as the aerobic bacteria in the activated sludge process of sewage treatment, have the property of destroying the stability of colloids, especially if the latter consist of organic material.

HOW TO DIMINISH COLLOID CONTENT

In connection with colloidal content of pulps, the old adage "an ounce of prevention is worth a pound of cure" is very applicable. A little attention to the treatment of a pulp before thickening will often cut down or even prevent the formation of colloids.

If the material is pulverized by a single pass through a grinding mill, while the harder pieces are being ground to required size, the softer particles may be reduced to the colloid class. This may be remedied by operating a classifier in closed circuit with the mill, as illustrated in Fig. 2.

A classifier is a machine to separate coarse solids from finer particles when they are mixed in a suspension. The separation may be made at any size from +20 mesh sand to -350 mesh according to the type of machine, adjustments, etc. The Dorr classifier, most widely used, consists of an inclined trough or settling tank and a set of rakes parallel and close to the inclined floor. The rakes are given a horizontal, reciprocating motion by energy from a drive shaft working through a cam, bell crank and lever arm. The larger solids settle to the floor and are gradually pushed by the rakes to the upper or discharge end of the tank, which is above the liquid level, whence they are conveyed back to the mill. The finer particles are kept in suspension and are overflowed into a launder at the other end of the classifier.

In chemical processes, the manner and speed of mixing reagents, the

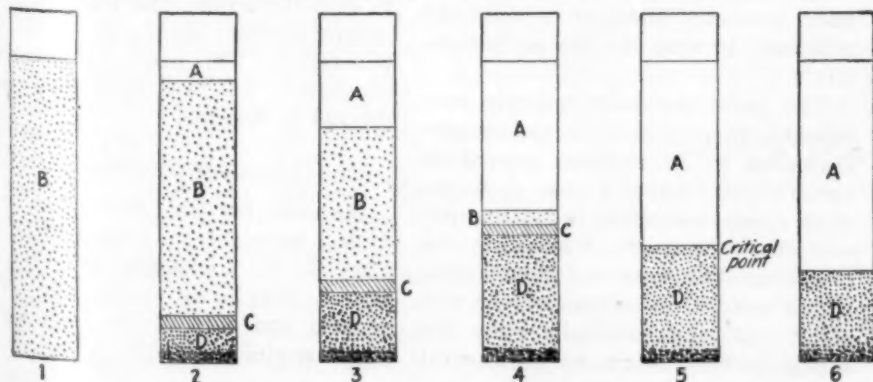


FIG. 1—EXPERIMENT SHOWING VARIOUS STAGES OF SETTLING



temperature employed and the means of conveying the mixture may effect the amount of colloids. Heating or roasting a finely ground material while dry will often prevent colloids forming in the mix.

DIFFICULTIES OTHER THAN COLLOIDAL

It often happens in both clarification and thickening operations that particles large enough to be classed as coarse suspensions will not settle. Months of experimenting are sometimes necessary to find the reason for this and to devise methods for overcoming it. A few of these difficulties follow, but here again the individuality of every problem is pronounced and no set rules can be formulated.

Exceedingly minute bubbles of air or other gas may become attached to the suspended particles, buoying them up against their own weight. If possible, the cause of the aëration is removed. If not, the mixture is agitated sharply by baffle plates or cascading to free the entrapped bubbles.

A small amount of foreign material may have the same effect. It has been found impossible to settle an ore on account of resins from rotten timber which had been ground with it. A few drops of oil will cause frothing in many types of suspensions, acting the same as in the flotation process of copper metallurgy.

What has been said of chemical treatment in preventing colloids may also be true when attempting to prevent this floating of coarser flocs. In one paper mill, in clarifying white water, trouble was encountered with floating material that would not settle. It was found that the floating was caused by alum used in the process and that the amount of float was roughly proportional to the amount of alum used. The alum was necessary in the process, so other means of overcoming the trouble were found. This time a long, wide trough, with baffles, used as a feed for the clarifier, was effective.

In all research and testing work, while a definite plan of procedure is used, experience and sound "horse-sense" are usually more valuable than theoretical knowledge.

THICKENING EQUIPMENT

With these general remarks on the nature of the thickening problem, we may proceed to consider the

equipment used in practice to obtain a thick sludge and clear overflow.

The settling question first became serious in metallurgy, in concentrating or dewatering ore slimes. For many years the intermittent or batch method was used, in plain settling tanks. The operation consisted in filling the tank, waiting for it to settle, and then decanting or siphoning the liquid, or drawing off the sludge from an opening in the bottom.

CONTINUOUS THICKENERS

The need of an efficient, continuous method was very pressing and received the attention of many mining engineers. Consequently, many devices were invented and used, but found small application on account of operating difficulties. To catalog these would be a monotonous task of doubtful value, so we shall touch only those developments that were widely adopted.

Continuous methods of thickening have effected very sizable savings in many chemical industries. Thickeners are very often used instead of or in conjunction with continuous filters, with a resulting saving of time, cost of filter cloths and skilled labor. In treating hot saccharate in the beet-sugar industry, for instance, these economies have been so pronounced that a complete thickener installation has paid for itself in 100 days.

One of the first continuous thickeners was the Callow cone tank, a cone-shaped settling tank with a suitable discharge valve at the point and a means of overflowing the clear liquid at the top. Its operation was a great improvement over the intermittent tank, but trouble was encountered in clogging of the underflow drain. The solids, instead of gravitating steadily to the point, would often build up on the sides and then suddenly slide, in a quantity sufficient to stop up the orifice entirely.

The Dorr thickener entirely surmounted these difficulties and its performance in all respects proved so satisfactory that its use soon became almost universal in settling operations. Its main feature is the revolving arms, carrying plow blades, which sweep the bottom of the circular tank and gradually rake the solids, as they settle, to the central

discharge. The clear liquid overflows the periphery and is carried off by a suitable launder.

The action of the rakes thickens the sludge to a high degree, while feeding the discharge uniformly. The underflow may be automatically controlled as to speed and consistency by Dorrco diaphragm pumps and may be raised to a considerable height by the Dorrco pressure pump. Since the capacity of thickeners is largely a question of area and space is often a valuable consideration in a plant, the Dorr thickener offers another advantage in the fact that several trays, with raking mechanisms, may be installed in a single tank, increasing the original capacity many times.

Continuous methods of thickening have effected very sizable savings in many chemical industries. Thickeners are very often used instead of or in conjunction with continuous filters, with a resulting saving of time, cost of filter cloths and skilled labor. In treating hot saccharate in the beet-sugar industry, for instance, these economies have been so pronounced that a complete thickener installation has paid for itself in 100 days.

Methods for increasing the rate of thickening have been devised, but most of these fall under the head of filtering rather than settling. The Genter thickener utilizes hollow filter candles which dip into the solution. Alternate suction and pressure are exerted from inside the fingers and as a result a layer of solids covers the outside of the finger which is dislodged and falls when the current is reversed. The solids fall to a cone-shaped bottom with a discharge opening at the point.

If an electric current is passed between electrodes dipping in water on opposite sides of a membrane, water will be forced through the membrane toward one electrode. In a suspension, if the membrane is made to stop the solids, the water will be separated from them and thickening will result. This phenomenon, called endosmose, has been used with some success in Europe.

ACKNOWLEDGMENT

Material for this article has been drawn largely from papers by H. F. Coe, G. H. Clevenger and W. A. Deane, previously noted, and from reports and data of the Dorr Company, engineers.



Filtration

PERHAPS no other unit process of chemical engineering comes closer home to the daily life of the average man than filtration. Almost every household has had experience with water filters in one form or another and coffee percolators possess an excellent filtration process. So it is that every production man is equipped with definite "filtration experience." The sad part of it is that frequently he does not make use of this elementary knowledge. So involved does he become in pressure, area, capacity and all the rest of the very necessary vocabulary that he often forgets the fundamentals.

That is one reason why in reviewing filtration we have asked one of the foremost experts in the subject

to return to fundamentals and discuss for you the very elements of it. Arthur Wright has done this supremely well. What does filtration do? What commercial equipment is available? What are the special fields of activity in which each type of equipment excels? What are the bases of filtration technique? By what methods is it customary to attempt to improve filtration? This general review is followed by a short discussion of filter presses, the most common types of filters. Following the Exposition Issue there will be articles on the modern technique and application of filters, upon special filtration problems that have been solved and upon the selection the correct filtering mechanism for a given problem.

Progress and Technique of Filtration

With Modern Equipment Control of Filtration Is Simple and Results Are Consistent—A Remarkable Development

BY ARTHUR WRIGHT

Filtration Engineers, Inc.

FILTRATION plays a prominent part in chemical engineering, for most chemicals and many related products require filtration in their manufacture. Filtration is a unit process in plant practice, not simply because the type of machine (which differs from grinders, mixers, evaporators, etc.) defines it as such, nor because it is often installed in a separate room or floor by itself, but more because we have today advanced in the art of filtration so that it is a branch of chemical engineering in itself.

Filtration is seldom the end point in the manufacture of any product but is merely a step in the process of its manufacture. As such it is frequently considered a necessary evil. This point of view arises far too often, sometimes from lack of knowledge of correct principles of filtration, but more often because the machine in hand is asked to do work beyond its capacity or design.

Industrial filters today function to a far greater extent than those of the previous decade. They are not only simple clarifiers fulfilling the popular definition of filtration—"separation of solids from liquids"—but do considerably more. The solids separated from the liquor can today be washed free of that liquor, so that when discharged from the machine they will carry a

trace only of the original liquid. The moisture content in the cake separated from the liquor need no longer be the high percentage formerly obtained from anything other than the plate-and-frame filter press, but can approach the minimum below which no water can be extracted by mechanical means. In the matter of discharging the cake, labor has been reduced to a minimum and filter cloth renewal is tremendously reduced. Yet, notwithstanding the added scope of the present-day filter, we still find installations of continuous filters where an exacting wash and a low moisture content are required. This is attempting more than contemplated in the design or capacity of the machine.

INTERDEPENDENCE OF UNIT PROCESSES

In the manufacture of many products no unit process is positively independent of any other, and filtration is surely no exception. Nearly 85 per cent of the problems in filtration are solved in the better pre-treatment of the material rather than in the selection of the mechanical design for filtering. The finest filter ever designed will not function if the material is not filtrable. The lowliest home-made affair will get some results if the material is rendered filtrable.

The importance of the pre-treatment of the material is, therefore, vital and it is not sufficient to know from laboratory experimentation how to precipitate the product so as to prevent slimy and amorphous formations. This is the first requisite and whenever the precipitate has a tendency to vary in its filtrability, those factors of temperature, density, etc., which govern the variations, must be controlled within narrow limits. Out in the plant this may not be the simple matter that it is with bunsen burners in the laboratory, but it is equally vital. A mixing tank supplied with steam coils or steam jacketed, or fed with perforated steam lines, must be equipped with an adequate agitator so that there is no localized overheating and so that a thermometer located anywhere registers the temperature of the whole mass. Many precipitates change form on long standing or by a change in temperature. Team work between the filter station and the mixing department should be secured so that delays between time of completion of mixing and feeding to filter can be eliminated. The two stations are too closely dependent to permit any other arrangement. With a liquor properly treated for filtration and with a filter installed, the control should be adequate to provide for proper clarification, cake building, cake washing, drying and discharging. Clarity was formerly held to be a function of the filter cloth used. We realize today that the true clarifying medium is the initial film of the solids being filtered from the liquor. We must



obtain filter cloth, therefore, primarily because it is free-filtering, easily discharged and resistant to corrosion.

FILTER CAPACITY AND CAKE WASH

When endeavoring to get the maximum capacity from the filter, the rate of flow, or, better, the maintenance of a high rate of flow, is the goal. This is no longer the simple matter of increasing the pressure, for too many materials are compacted and further resist the liquid flow through them under high pressure. The individual material has its own filtering characteristics and must be operated accordingly.

In washing the cake there is no good reason for being satisfied with any soluble content in the discharged cake above the desired limit. It is common practice to be able to extract the solid from the cake with an amount of wash water less than the volume of cake and still have the wash uniform without. When all of the wash water must be evaporated to a thickened liquor, step-washing, by which the gravity is gradually increased, is the accepted method of reducing the amount of evaporation required.

Drying the cake is rightfully being given more attention. Often the cake is a waste product and its dryness as discharged from the filter is of small moment save that the drier the cake as it leaves the filter the less possibility of an unwashed cake being thrown away. Filtration bears a definite relation to the unit process of drying particularly in this part of the filter operation. The less moisture in the cake leaving the filter and entering the drier the less heat required to dry the cake. Again we have advanced in the art of handling

the filters so that the moisture content can closely approach the limit below which no more water can be extracted mechanically. In recent years self-discharging and automatic filters have been adopted in many plants. The keynote of success in these machines lies in the complete discharge of the cake. The combination of more enlightened design and better methods of operation has resulted in a uniform success so that there should be few instances where this is not easily accomplished and positively obtained at all times.

The control of the filtration is tied up very much in the matter of the proper selection of layout of the auxiliaries to the filter. There is nothing complex in the matter of the proper, feed pump, location of vacuum receiver, control valves, etc., but there is a wide variation in the emphasis placed on these details. It is almost axiomatic that a filter is as good as its auxiliary equipment. That a simple change in auxiliary equipment in a filter installation giving doubtful satisfaction can make the same installation give complete satisfaction is vivid proof of the value of correct layout.

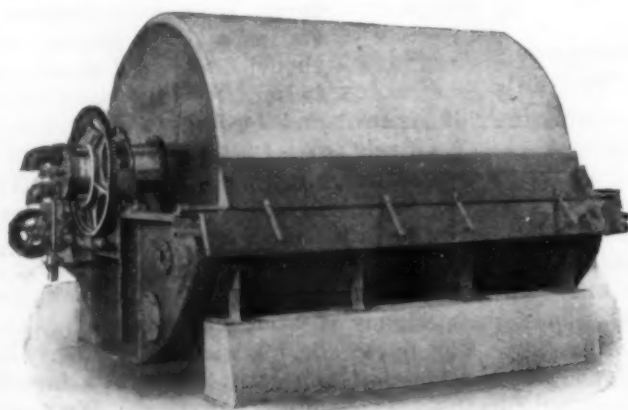
EFFECT OF FILTRATION ON SUBSEQUENT OPERATIONS

Just as filtration is dependent upon the pre-treatment of the liquor to be filtered, it is likewise true that filtration bears an important relation to the after processes. It is an easy matter to trace the dependence of evaporators, stills, driers and decolorizing equipment to the correct functioning of the filters. The filtering process is positively not complete if it does not have as its end pre-filtering the material for the next process.

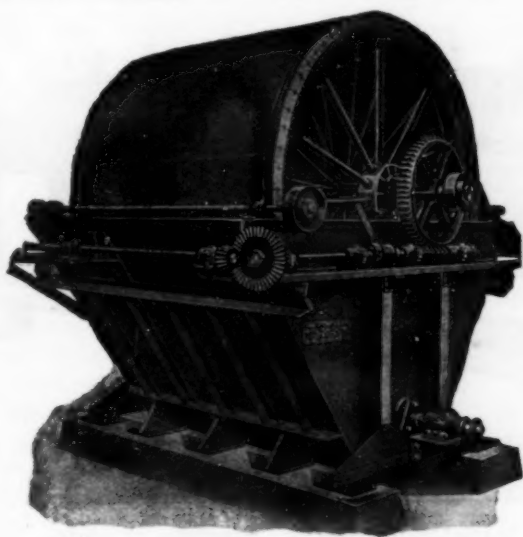
For evaporation of the filtrate the filters must clarify the liquor, must handle the liquor at the maximum practical density and in the case of hot liquors the layout must be such as to pass the hot filtrate to the evaporator without allowing the heat to dissipate. Clarification is often a matter of the control of the operator. On some intermittent types of machines this is inherent in the scheme of operating them. For most continuous filters, however, the design should incorporate a refiltration of the first filtrate, obtained as the compartment first dips into the liquor, and should pass on to the evaporator only the filtrate obtained after the formation of a thin cake of material on the cloth which acts as a true filter medium. Many plants now have the matter of mixing, precipitation, etc., down to a fine control so that the filtrability of the solid is practically uniform. In these plants it is possible to ascertain the critical density at which the material should be filtered. If, however, the characteristics of the solid vary, an average density is the best that can be attempted. To wash the cake with the minimum water is naturally desirable if the filtrate must be evaporated. Often the water consumption can be minimized best by several washings, the first being the relatively strong liquor and becoming weaker step by step till it reaches zero concentration or water. The production of excess weak liquors has no place in modern filter practice. When liquors filtered from precipitates of calcium sulphate are evaporated, scale formation on the heating surface of the evaporators is almost inevitably due to the precipitation of the calcium compounds during concentration. To aggravate the scaling tendencies by delivering a liquor containing calcium (or magnesium) solids in suspension is, of course, poor functioning of the filter.

Distillation is dependent on previous filtration in much the same way as evaporation. However, the final distillate is often most distinctly affected by faulty clarification so that it can be even more important than in evaporation.

In a sense, filtration and drying are synonymous. Take the popular definition of filtration as the separation of solids from liquids, it is only completely fulfilled when the solids are dried to zero moisture. Consequently the relation between filtration and drying is very close. The better the work of the filters in sep-



TYPICAL ROTARY FILTER—THE OLIVER



ANOTHER TYPE OF ROTARY FILTER—PORTLAND

arating the solids from the liquor and in delivering to the drier a well-dewatered solid the less arduous will be the work of the driers. To prepare the cakes leaving the filter so as to have the moisture most accessible for drying is an additional function of the filter. Often there is a wide difference in the operation of a cylindrical drum drier of the cement kiln type between a cake carrying 27 per cent moisture and one carrying 24 per cent moisture. The balling-up effect is much greater in the former case. Upon analysis it would have been found that at 24 per cent the free moisture, removable by mechanical means, is very small, so that the 3 per cent excess in the cake having 27 per cent was sufficient free moisture to make the cake sticky instead of crumbly.

The art of filtration has advanced so that the control required even with intermittent filters of modern design is a matter of routine. The most unskilled operator has developed to an expert handler of such filters in less than a week's time. Filter cloth can be designed resistant to corrosion, so that renewals on this score can be almost eliminated. Replacing filter cloths because they become plugged up should be infrequent if the proper kind of cloth is selected for the material in hand. The power consumption is a matter of correctly apportioning the auxiliaries for the work in hand, so that the machines operate close to their efficient characteristics.

Filtration should be a means of quickening production so that the

turnover is a maximum. The use of those machines requiring long filtering cycles in their proper operation is an example of poorly selected equipment. It is not keeping pace to continue filtration when the rate of flow has fallen below the economi-

cal limit simply to get sufficient cake for the proper discharge. If the frames of a plate-and-frame press are so wide as to require this sort of operation, it is time to cut down the width of the frame. If a continuous filter is rotated at a slow speed, in order to get sufficient cake thickness for its discharge, it is proof that the liquor should have been thickened or handled by other means.

Filtration has an important and permanent place in chemical manufacture and chemical engineering. Its possibilities are greater now than at any time previously, but the chemical industry can well thank the mining field for the introduction of the cyanide process of recovering gold and silver. Filtration received a greater impetus and a more extensive development in the early days of the cyanide process than at any other time. Recollection of the names of Merrill, Burt, Moore, Sweetland, Butters, Kelley, Oliver and Dorr, all mining men, alone bears proof of the debt chemical engineering owes to mining in the field of filtration.

The Filter Press in Filtration

Discussion of the Elements of Design, Construction and Operation of Filter Presses—Some Points to Consider in Selecting a Press

BY M. J. SAYLES

Independent Filter Press Co.

FILTRATION is essentially the process of separating the solids from a mixture of solids and liquids. There are three conditions necessary in order that filtration may take place. First, there must be a filter, which is a machine devised to support a filter medium. Second, there must be a filter medium, which is a porous substance, usually cloth. In modern practice the filter medium is usually the material itself and the cloth acts as the matrix on which the material may build itself up as a cake. Third, a difference in pressure between the two surfaces of the filter medium sufficiently large to cause the liquid to flow through is necessary. The simplest filtering device is the laboratory filter funnel. The funnel is the filter. The filter paper is the filter medium, and the difference in pressure between the upper and lower surface of the liquid in the funnel causes the filtrate to flow through.

For practical purposes, the rate of filtration is roughly proportional to the filtering area and to pressure applied. Commercial filter designs are based on these two important principles. The essential thing is to have as large an area of filter medium as possible with a minimum of floor space and so designed that a difference of pressure can be created on either side of the medium, thus forcing the liquid through.

Of the many types and designs of filtering machines that have been produced, filter presses embody these principles to a very high degree with simplicity of operation. The filter press was invented in England more than 60 years ago. The first press manufactured was the center feed recessed plate type. The flush plate-and-frame type was developed later.

Filter presses may be divided into the two main groups just mentioned, the recessed type and the plate-and-frame type. In the recessed filter



press the cake is formed between two recessed plates. Each plate is hollowed out on both sides and forms a chamber with the successive plate. This chamber holds the cake when filtration takes place. The thickness of the cake in this press is limited to 1½ in. The recessed type press is usually center feed. The plate and frame type press has flush plates and frames.

PRESS OPERATION

After the filter cloth is placed over the plates, the press is closed as tightly as possible. All the spigots should be left open. The pressure, whether pump or compressed air, is then applied to the mixture which is to be filtered. During the initial stages of filtration the pressure is small. As the cake deposits on the cloth, the latter ceases to act as the filter medium, the former taking its place. The cake offers greater and greater resistance to the flow of the liquid. The pressure increases until a maximum is reached beyond which efficient filtration ceases. At this point the pressure is discontinued, the press opened and the cake removed. The time required to filter a batch is dependent on the size of the press and the physical characteristics of the material. Some products filter at the high rate of 10 gal. per sq.ft. of filtering area per hour, while some colloidal substances would have a filtration rate of almost zero. Where substances are hard to filter, the chambers should be not thicker than 1 in. and the pressure should be applied gradually.

WASHING IN THE PRESS

Washing is resorted to for two reasons, either to recover a valuable liquor from the solid particles which retain it or to free the solid matter from impurities in the mother liquor. There are also two general methods of washing, the simple wash and the so-called through wash. In the simple wash method the feed channel is used for the admission of the wash water. For best results with this method the cake should not be fully formed, but left incomplete with a hollow center into which the wash water passes. While in some instances satisfactory results are obtained, there are distinct disadvantages to the system. Care must be taken that the proper amount is fed into the press, for a solid cake will prevent even washing. Also press capacity is wasted and more labor is consumed in emptying the press, for

a firm cake is dislodged more readily than a loose cake. The other method, the through wash, is more satisfactory.

The through washing press has either one or two ports in the head of the press on the opposite side of the feed port. These ports form a channel with corresponding ports in the plates, every other plate being cored so that the wash water reaches the plate surfaces. The cored plates are called wash plates. Before commencing to wash, the spigots on the wash plates are closed and those of the intermediate plates are left open. The wash water covers the surfaces of the wash plates, and since it cannot pass through the closed spigots, the pressure forces it through the cake, and it escapes through the open spigots of the intermediate plates. In the plate-and-frame press the cake formed is of uniform thickness and permeability and hence the wash is thorough and uniform. Employing this method, a number of manufacturers have succeeded in the last few years in reducing the time required in producing batches, either by eliminating decantation washing or by reducing the number of decantations. The wash inlets can also be connected with compressed air and upon completion of washing, air is allowed to enter the press in the same manner as the wash water. It will reduce the moisture content by displacing it.

WHAT IS THE PROPER PRESS TO USE

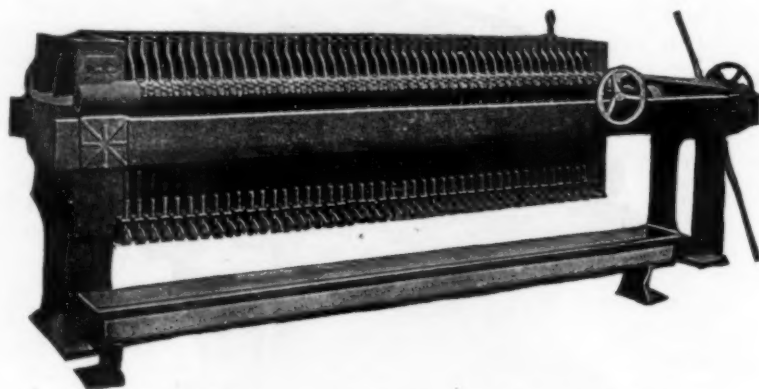
To decide the size and type of press required, the following factors should be considered: Where the percentage of solids is very small and the liquor is to be retained, the recessed type is preferable. Their first cost is less than that of the plate-and-frame type, and there is less

handling of plates. For most other purposes the plate-and-frame type is more suitable. If the material filters easily, a frame thicker than 1 in. can be used. In the large majority of cases the open delivery press is of course desirable, being simpler and more easily controlled. Closed delivery presses are necessary where the filtrate must not come in contact with the air. If there is a valuable liquor to be recovered from the cake or if the cake is to be freed from impurities, a washing type press should be used.

DETERMINING THE SIZE

The size of the press required is determined by the quantity to be filtered, the physical characteristics of the material, the percentage of solids in suspension and its specific gravity. As previously stated, filtration is proportional to the filtering area. The number of gallons to be filtered in a given time is a large factor in determining the filtering area required. The rate of filtration depends on the nature of the material, whether granular or colloidal. The percentage of solids and its specific gravity will determine the cubical capacity of the press. It is possible that a press will have sufficient filtering area to handle a batch in the required time and its cubical content be too small to retain all the solids. In that instance, a larger press or one with a thicker cake, if permissible, is more suitable. The chemical nature of the mixture will determine the kind of press required, whether wood or iron or some special metal.

Of course this short discussion attempts to present merely the barest outline of filter press technique. Rather consider it an enumeration of some of the problems and difficulties.



TYPICAL FILTER PRESS INSTALLATION—SHRIVER



Centrifugal Separation

THERE is something about the centrifuge that inspires confidence and respect. In boyhood days on a farm we used to marvel at the miracles so quickly and efficiently performed in grandmother's cream separator. And just the other day with much the same sort of fascination we stood before a 54-in. sugar extractor and watched it whirl and wash its crystalline load free from the pasty *massecuite* and gummy mother liquor. Perhaps it is because of this inherent respect and implied efficiency that few of us are astounded by the ever-broadening application of centrifugal separation in our industries. Such a remarkable accomplishment as the clarification of mixed acid in a high-speed centrifugal of Monel metal is taken as a matter-of-fact development, simply because we have learned to expect just such performances. A half-million dollar installation for the centrifugal refining of lubricating oil attracts no more attention today than the erecting of a new gasoline filling station. These seem

but steps in the logical development of this branch of technology.

Subsidence of suspended solids is usually a slow process and sometimes a costly one, for large capital investments may be tied up in material in process. Substituting the centrifuge brings to play a force many thousand times that of gravity and naturally we expect to accelerate the rate of reaction and to improve the results obtained. Removing the last traces of water from nitrobenzol or purifying and dehydrating a dirty transformer oil are examples worthy of more than passing note.

Research is constantly broadening the field of the centrifuge. Developments made over night are revolutionizing some of our chemical engineering industries. It is time to take stock and to appreciate the way in which this efficient tool of the chemical engineer is solving many difficult problems in production. This is the purpose of the articles which follow.

Is There a Centrifugal Solution for Your Production Problem?

Substituting Centrifugal Force for Gravity Improves Existing Processes, Recovers Values From Waste Products and Generally Speeds Up Production

BY LEE H. CLARK

Centrifugal Engineer, Sharples Specialty Co., Philadelphia

CENTRIFUGAL force as a means for effecting separations finds its application in two very distinct types of equipment. The origin of the force is the same both in the perforated basket extractors, or driers, and in the solid wall clarifiers and separators. On the other hand, the principles underlying the separations effected by the two types are totally different.

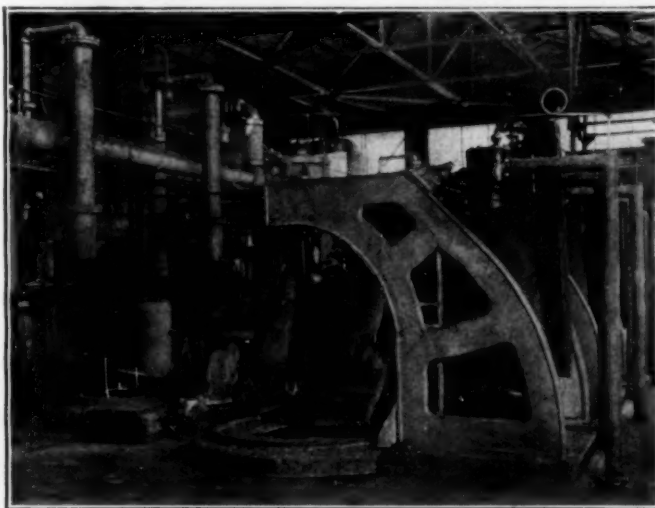
Freeing a solid of adhering liquid in a centrifugal extractor may be compared to filtration under pressure. The wall of the basket is lined with a screen, or filter medium, of sufficiently fine texture to retain the solid while allowing the liquid to pass. Centrifugal force develops a pressure in the direction of the periphery throughout the charge in the whirling basket. The

solid is retained in place by the filter, whereas the liquid, being free to flow, passes through the solid, through the filter, and is thrown clear of the basket. The completeness of the extraction will depend

upon the centrifugal force developed, the size and uniformity of the solid particles, the presence or absence of gelatinous materials and the extent to which the particles absorb liquid.

SUBSTITUTING FOR GRAVITY

Centrifugal separations in the solid wall type machines are analogous to gravity settling operations. Gravity will tend to effect the subsidence of insoluble materials suspended in liquids if there is a difference between the specific gravities of the two phases. In the clarifiers and separators, centrifugal force is substituted for the force of gravity. As the direction of the force is outward from the axis of rotation, a suspended material heavier than the liquid will tend to pass through the liquid toward the periphery and deposit on the wall of the machine. Particles lighter than the liquid will tend to pass toward the axis of rotation and collect on the inner surface of the liquid. Although some types of clarifiers are equipped with filters to remove solid particles unaffected by centrifugal force, the essential action of the clarifier is strati-



DRAIN TABLE AND CENTRIFUGAL DRIER AT THE ROSEDALE PLANT OF THE CAMBRIA STEEL CO.

Crystals of ammonium sulphate which fall in the saturator are thrown out by an air ejector onto draining tables. The liquid mixed with the crystals overflows and is returned to the saturator. At regular intervals the salt is paddled into the centrifugal driers.



GEE CENTRIFUGAL SHOWING PLATES RAISED ABOVE BASKET FOR UNLOADING

fication of the particles by subsidence, to which the introduction of the filter is supplementary. In the simplest type no filter medium is used. The particles form a layer outside of the path of the liquid through the bowl and do not obstruct the passage of the liquid.

The degree and rate of separation will depend upon the specific gravities of the components of the mixture, the size of the particles of suspended material, the viscosity of the suspension liquid and the magnitude of the separating force developed by the machine.

The type of centrifugal employing the principle of subsidence has been very successfully applied to problems demanding the separation of two immiscible liquids, as well as to the removal of solids from liquids. The extractor by its very construction is limited to solid from liquid separations.

FEATURES OF THE EXTRACTOR

The chief characteristic of the centrifugal extractor, or drier, is its perforated wall basket, lined with a woven wire screen, over which may be placed a suitable filter medium. The baskets are either under- or over-driven. Commercial sizes vary from 30 in. to 72 in. in diameter. They are usually 24 in. or less in depth to allow easy access for unloading. In general, they develop a centrifugal force from 200 to 600 times the force of gravity.

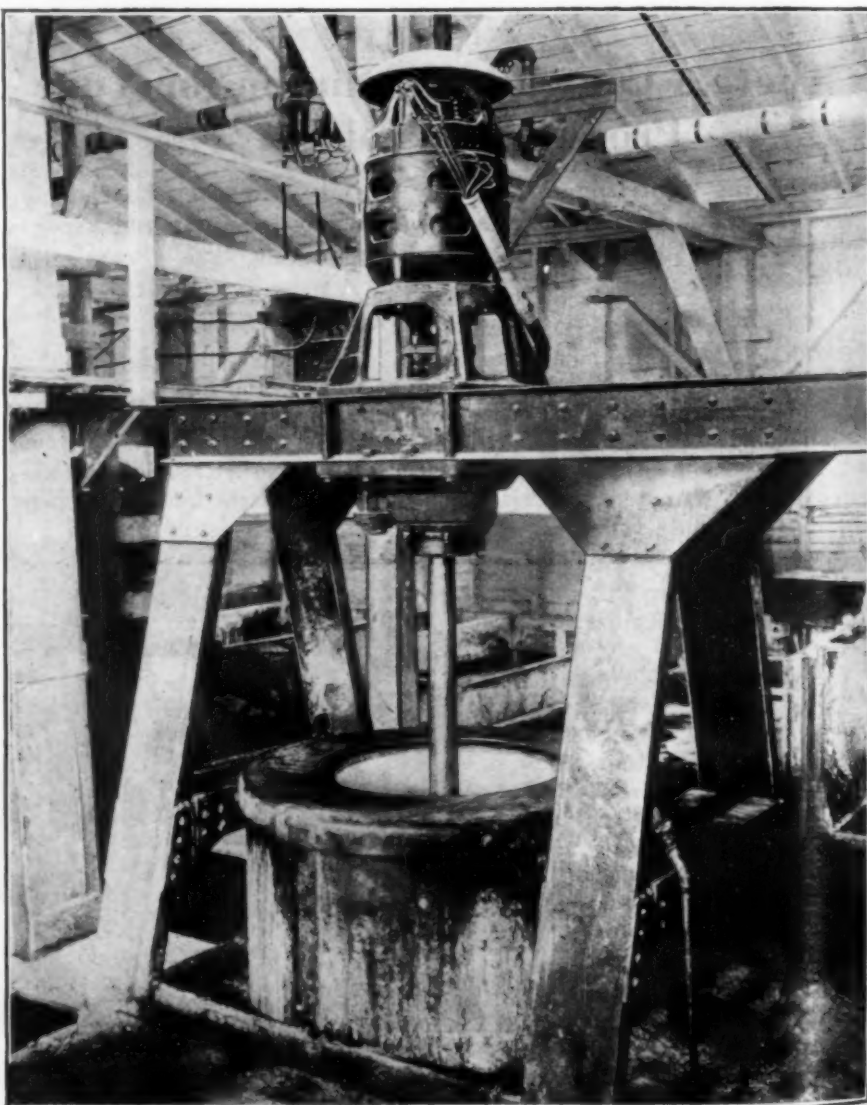
The basket revolves in a cast curb which serves as a collector for the

expelled liquid. A gutter at the bottom of the curb carries the liquid away.

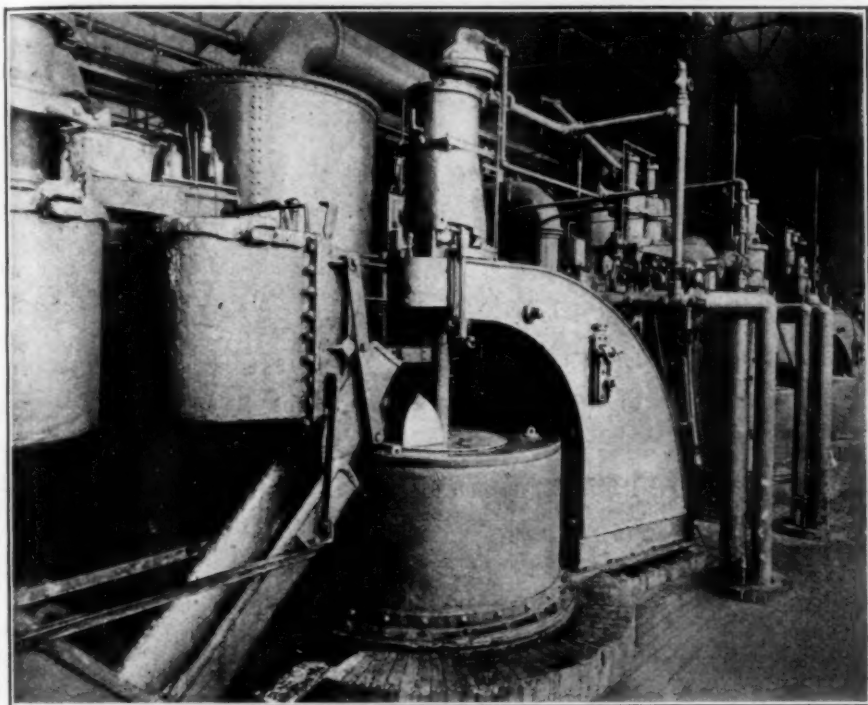
For unloading fine solids, the bottom discharge extractor is used. If the dried material is bulky and easily handled, the machine may be unloaded from above. Textile, dry-cleaning and laundry extractors are of the latter type.

The Elmore extractor has the unique advantage of discharging the dried solids continuously. The solids deposit upon the sloping wall of a perforated basket. Scraping flights, revolving at a lower speed within the basket, remove the solids as they accumulate, discharging them separately from the liquid.

In operating the standard type of extractor, the basket is charged with the machine revolving at low speed, while the liquid containing the crystals is fed in. When an even distribution of the charge has been obtained, the machine is brought to



MOTOR-DRIVEN CENTRIFUGAL
Drying sodium phosphate in a Southern chemical plant.



STEAM TURBINE-DRIVEN CENTRIFUGAL

Drying ammonium sulphate at Henry Ford's byproduct coke plant. The sludge box at the left is used to hold the wet crystals until there is sufficient quantity for a full load in the centrifugal. The charging chute is then reversed, the valve opened and the material dumped into the machine.

its normal speed and maintained there until the crystals are sufficiently dry.

In the manufacture of refined sugar, the *masse-cuite*, consisting of sirup mixed with sugar crystals to form a paste, is fed into the revolving perforated basket. The crystals are freed first from the bulk of the molasses, and are then given a wash with water or a concentrated sugar solution in order to remove the last of the mother liquor. Coming from the centrifugal, the sugar contains from 3 to 5 per cent of moisture, which is removed in a heat drier.

Centrifugal extraction is usually followed by other methods for obtaining a technically dry product. However, it is a particularly useful means for obtaining solids free from the bulk of their mother liquor. Such heavy chemicals as ammonium sulphate, glaubers salt, sodium carbonate and bicarbonate, copper sulphate, salt and silver nitrate are dried centrifugally. Among the organic materials so handled are anthracene, naphthalene, aniline salts, carbofic, citric, sulphonic, picric and salicylic acids, camphor, innumerable dyes and intermediates and starch.

The textile industries use extractors for drying dyed and washed fabrics. They are employed widely for laundry drying and by dry cleaners to remove the gasoline from washed garments. An important ap-

plication is the recovery of oil from waste and from the chips and turnings from cutting machinery. Gun-cotton is freed from acid, washed and dried in extractors.

It is easier to handle crystalline solids than to dry amorphous or gelatinous precipitates with the extractor. Even crystalline materials become increasingly difficult to free

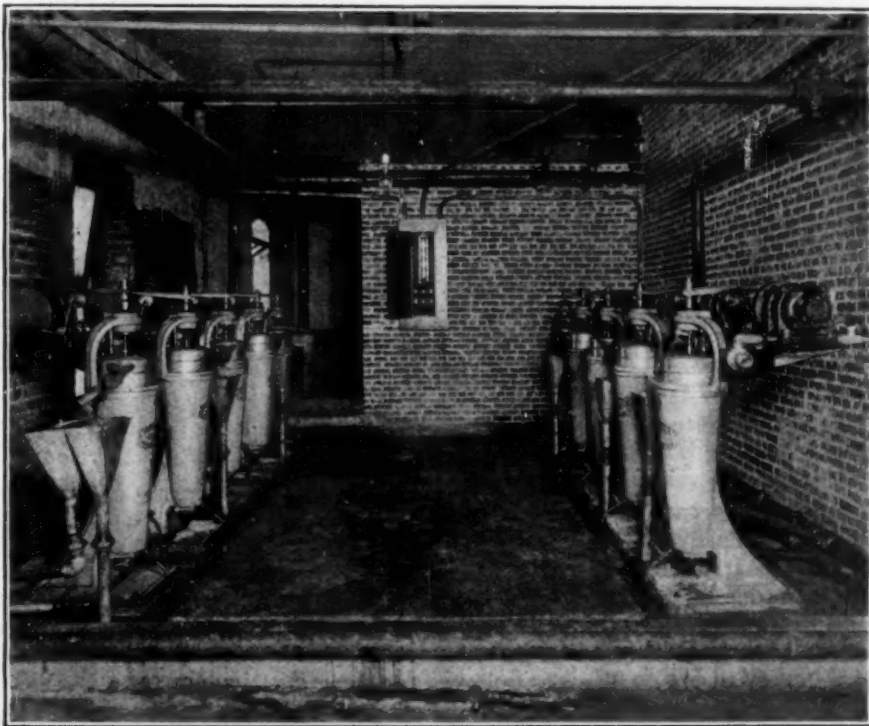
from moisture as their fineness increases.

Generally, the mixtures fed to the machine contain more solid than liquid, and are charged as a paste. The filtration of large volumes of liquid containing under 40 to 50 per cent of solids is usually slow and uneconomical with the extractor. The liquid must all pass through the solid cake formed in the basket. As the cake accumulates, it tends to obstruct the passage of the liquid and the rate of filtration falls off materially before the basket contains a sufficient load of solid.

BULK CENTRIFUGALS

The solid basket centrifugal of large diameter has been called a bulk centrifugal to distinguish it from the smaller diameter high-speed clarifier. The bulk machine has a large capacity for solids as compared with the high-speed centrifugal, and is particularly applicable to the recovery of solids from suspensions containing up to 40 to 50 per cent of insoluble material. Its chief function is solid recovery or liquid clarification. The dryness of the cake formed is not comparable to that obtained by the extractors.

These centrifugals are designed for the removal of solids both lighter or heavier than the liquid in which they are suspended. The material is fed in continuously with the basket at full speed. The solids remain



SHARPLES SEPARATORS RECOVERING COTTONSEED OIL FROM SOAP STOCK



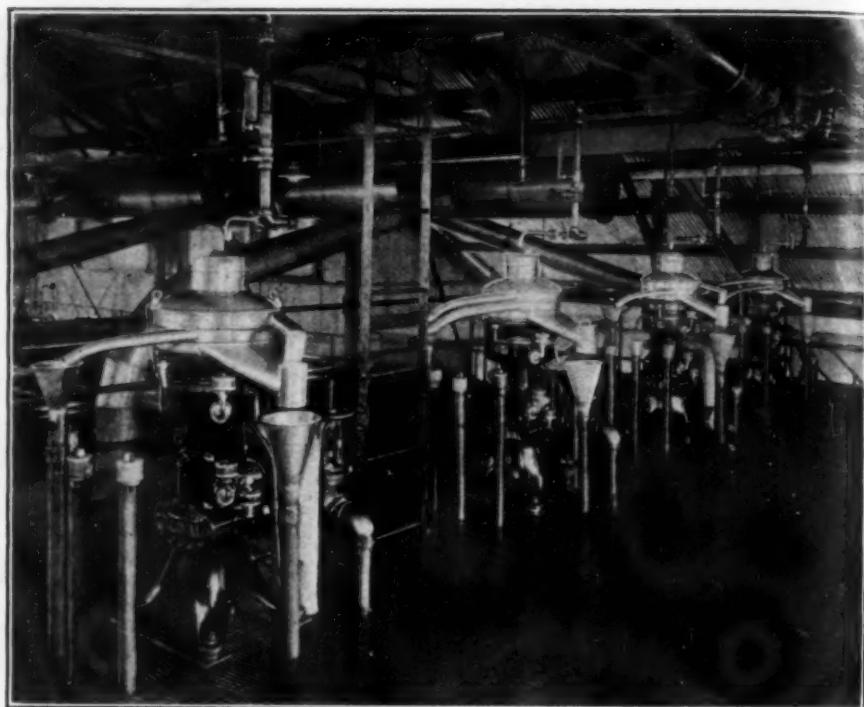
in the basket while the liquid is discharged. The operation is continued until the basket contains a full charge of solids. Then the feed is cut off, the machine stopped and the solids discharged.

Except for their solid wall baskets, many of these machines resemble the extractor in design. Two types of these machines showing interesting variations are the Gee and the Resines.

The Gee, used in England and recently introduced into this country, has a basket 36 in. in diameter by 54 in. in depth, revolving at 1,000 r.p.m. The added depth permits more effective clarification by allowing the liquid a longer path of travel while under centrifugal force. The solids are deposited on plates, which line the basket wall, the plates being lifted out with the adhering solids after the machine is stopped. There is a filter placed upon a cone in the bottom of the drum to retain solids that fail to come out under centrifugal force. The filter is "self-cleaning" in that any appreciable cake that builds up on its surface is thrown off to the plates. The machine has been used for the purification and grading of china clay and ocher, for the recovery of cattle feed from distillery slop, the clarification of wort before fermentation, and the recovery of paper pulp, coal and other products from waste waters.

The Resines obtains a longer path for the liquid to travel by the introduction of a series of horizontal baffle plates in the basket. The liquid is introduced by a pipe running to the bottom of the basket, passes upward alternately over and under the baffles, and discharges into the curb. The design of the machine parallels that of the Weston sugar centrifugal, except for the solid wall and baffles of the basket. The machine has been used for the clarification of raw sugar liquors, tanning extract, in the paper pulp industry, and for miscellaneous clarifications.

The bulk centrifugal is useful for handling large volumes of liquid containing a large percentage of solids. It has the disadvantage of failing to clarify most materials completely, and in order to produce clear liquid the action of the machine must be supplemented by other means. It is valuable in that it will make subsequent and final clarification in either a filter or high-speed centrifugal more rapid and less laborious, re-



FOUR DE LAVAL OIL PURIFIERS REFINING LUBRICATING OIL IN THE PLANT OF THE ASSOCIATED OIL CO., AVON, CALIF.

ducing the cleaning period of the latter equipment. Using no filter medium, it does not clog as the clarification progresses.

Where partial clarification or recovery is all that is desired, either from the nature of the product or the use of subsequent methods for clarification, the bulk centrifugal is a very useful machine.

HIGH-SPEED CLARIFYING

To withstand the great centrifugal force that it develops, the high-speed centrifugal is of relatively small diameter. For that reason it has a restricted capacity for solids, and it is impracticable to use it for clarification requiring the removal of large quantities of solids, unless the value of the product recovered is above the average. Generally its usefulness is limited to the clarification of liquids containing 2 per cent or less solids. A proper relation must exist between the value of the products of clarification before and after treatment and the labor cost of cleaning the rotor. Frequently the bulk of material may be removed by a preliminary settling, screening or treatment in a bulk machine.

The Sharples clarifier has a tubular rotor or bowl 4 in. in diameter by 30 in. long. The rotor revolves at 15,000 r.p.m., developing a centrifugal force 13,200 times the force of gravity. This force is the only clarifying medium, there being no filter or other device to assist the re-

moval of suspended material. The liquid is fed in from below. As it travels upward in the rotor solid particles are removed, and the clarified liquid discharges into covers.

The rotor of the De Laval clarifier is 12 in. in diameter by 16 in. It is driven at 6,000 r.p.m. and develops a force 5,560 times the force of gravity. The clarifying effect of centrifugal force is supplemented often by conical disks placed in the rotor and occasionally by filters. The liquid is fed in at the top, passes to the bottom, where it is distributed, and returns upward to discharge into covers.

Both machines are applicable over much the same field. They are extensively used for the clarification of animal, mineral and vegetable oils, pharmaceutical products, extracts and a wide variety of other miscellaneous liquids containing a small amount of almost colloidal solid material. They are particularly useful on viscous liquids that filter with difficulty, such as varnishes, lacquers, mucilages, shellacs and gum solutions. For varnish manufacture they have become standard equipment. Being easy to clean, it is possible to clarify many different grades with but a short interval between runs. There is no loss of varnish in the apparatus and little loss in the solids removed.

By adjusting the speed of the machine and the rate of feed, they can be used for selective clarification,



removing particles in proportion to their size and density. In clarifying paints and enamels, coarse foreign material and unground pigment particles that would mar a surface when applied are removed, while the fine pigment is left in suspension.

The use of the machines for the continuous removal of impurities from used liquid is one of their most important functions. The "continuous flow process" employed for the regeneration of dry cleaning solvent is an excellent illustration. The solvent, carrying the dirt removed from the clothes in the washer, flows to the clarifier, which removes the dirt, and returns clean solvent to the washer continuously throughout the washing process. Instead of washing and rinsing in batches, using fresh solvent for each rinse, the original solvent is regenerated and re-used. The capacity of the machine must be high and constant, as the more often the gas in the washer is circulated the quicker the cleaning.

The continuous system has been applied to the regeneration of turbine, Diesel engine and cutting oils. Connected into the oil system, the clarifier receives the used oil and returns a clean oil, free from moisture, carbon, breakdown sludge and grit. Saving of oil, less wear upon bearings, better power production and longer engine life have been demonstrated for the method. The clarifier is an automatic guardian, assuring a satisfactory lubricant at all times. A batch system of regeneration results in good oil only periodically;

most of the time the oil in service is unfit for good lubrication.

Transformer and insulating oils are periodically centrifuged to restore their dielectric strength.

High-speed centrifugal treatment in many cases results in an enormous increase in the rate of separation; in a definite and complete separation in which both constituents are delivered substantially free from the other, and in separations impossible by gravity or lower forces.

The rapidity of separation has been utilized to minimize undesirable bacterial reactions; reduce loss of volatile liquids by evaporation; prevent loss of flavor in fruit products; and eliminate decomposition by slow chemical reaction.

CENTRIFUGAL SEPARATION

Both types of high-speed machines previously described for clarification work have been adapted to separation problems. By a proper modification of design both components of a two-liquid mixture are discharged separately and continuously.

From a centrifugal viewpoint there are two distinct classes of two-liquid mixtures. True emulsions consist of microscopic globules of one liquid suspended in another containing an emulsifying colloid, which prevents coalescence of the suspended liquid. There are other two-liquid mixtures in which no colloid is present or, if present, so weak as to offer no resistance to centrifugal force. It is not infrequent for both conditions to exist in the same mixture.

In handling true emulsions, the suspended globules of which are protected by a strong emulsifying colloid that prevents coalescence, it is usually necessary to carry out two complete centrifugal operations. The first operation is designed to obtain the concentration of one liquid still in an emulsified condition; the second operation to deliver both liquids in a free state.

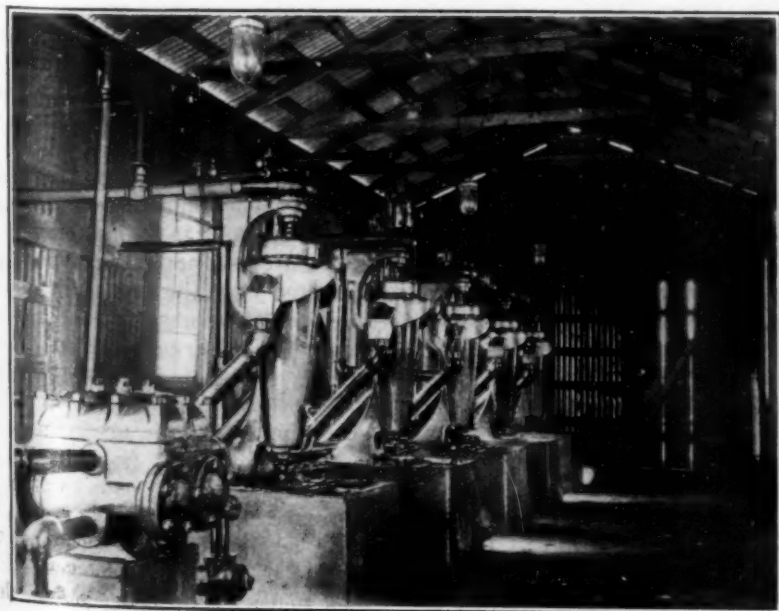
In the recovery of cottonseed oil from soap stock, a primary run upon the diluted soap stock yields on the one hand a water solution containing most of the soap dissolved in it, and on the other a creamy emulsion rich in the oil phase. This concentrated emulsion is then diluted with water and sufficient saturated salt solution added to break the emulsion. The secondary run yields free oil and an aqueous salt solution free from oil. It is impossible to break the emulsion in such a way as to obtain free oil before the first centrifuging.

By properly applying the principles of emulsion resolution, butter oil is recovered from milk and cream, a great number of animal, fish and vegetable oils are recovered from soap stock, amyl acetate is recovered from salt water, orthotoluidine from hydrochloric acid solutions, and wool grease from wool-scouring liquors.

In the absence of a strong emulsifying agent, one centrifugal operation is sufficient to coalesce suspended globules and to recover both constituents of a two-liquid mixture, each substantially free of the other. Bone grease, butter fat, coal-tar oil, fish-liver oil, many essential oils, fatty acids, tallow, transformer oil, water-gas tar and wool grease are examples of materials dehydrated in this manner.

Crude petroleum emulsions are sometimes separated by a single centrifuging. Frequently two runs are necessary for complete recovery of the oil.

The separator is being widely adopted for the removal of amorphous wax from distillates and cylinder stock in the refining of petroleum. As compared with gravity settling, its use offers increased economy and a better yield of oil, together with a lower pour test in the oil itself. The oil to be dewaxed is diluted with naphtha, chilled to precipitate the wax, and centrifuged. Water, introduced at the top of the separator, forms a layer upon which wax will float. The



SHARPLES SEPARATORS DEHYDRATING CRUDE PETROLEUM



diluted oil is discharged free from wax. The water, acting as a carrier for the wax, discharges with it.

The application of centrifugal clarifiers and separators of the high-speed type was confined principally

to the dairy industry until a little more than a decade ago. Their use has grown remarkably since that time and promises to continue. Research is constantly opening up new fields of application.

A New Field for the Centrifuge?

Bureau of Mines Studies in Applying Centrifugal Force to Ore Dressing Show Some Promise, Although in Most Instances Cost and Mechanical Development Are Limiting Factors*

BY OLIVER C. RALSTON

Superintendent Pacific Experiment Station, Berkeley, Calif.

DURING the past spring it was arranged that several technical journals should announce that the U. S. Bureau of Mines was investigating the possible uses of centrifugal force in the metallurgical field, particularly as it related to ore dressing. The correspondence that resulted was voluminous; most of it comes from inventors who feel they can prove that their machines will meet certain definite needs and many of whom are under the impression that "the government" will undertake the development of their ideas.

It is too early to state whether successful machines exist for the purposes for which centrifugal force might be applied; but it is possible, as a result of this correspondence, to outline more or less the fields under study and the possibilities therein for the use of centrifugal force.

REMOVING TURBIDITY

*Centrifugal clarification of water, or of liquids containing finely divided solids which cause turbidity, is a field in which a considerable amount of work has been done; and machines are available for the clarification of liquids in which centrifugal force of greater magnitude than that found in any other commercial operation is used—the so-called high-speed centrifugals. Occasion for the clarification of turbid waters in ore dressing arises from a variety of sources. Overflow water from thickeners or settlers, if discharged into streams, is occasionally objectionable. A centrifugal can be used for clarification purposes, but it is usually possible to build a tailing dam of sufficient size to remove, by sedimentation, almost all of the turbidity. Where the

turbidity is persistent, the flocculation of the solid particles may usually be insured by the addition of lime, alum or other agent. It is possible to conceive of conditions where settlers and flocculating agents could not be used, but these are rare, and the power consumption of a centrifugal clarifier makes its

It is possible to say that the centrifugal clarification of water containing valuable minerals, the centrifugal dewatering of thickened material, centrifugal amalgamation and centrifugal concentration are the four uses of centrifugal force which seem to be feasible, due regard having been paid to the costs of operating centrifugal machines. The mechanical development necessary to supply machines of this type is costly.

use uneconomical. If the turbid overflow comes from a concentrate bin or thickener and if the solids in suspension are valuable, it is possible that centrifugal clarifiers can find a field. The question requires careful study.

THICKENING AND DEWATERING

The use of centrifugal thickeners has been suggested, and there is no doubt that such machines occupy little floor space and that occasion will be found where their use, if erected high up in a building, will obviate passing a stream of pulp down a considerable distance to a thickener, to be afterward pumped back up to the point where it is needed. A centrifugal thickener would have to be designed for continuous feed, as well as continuous discharge of thickened product and clear water, and it is conceivable

that the centrifugal force causing the separation could also be used for pumping the separated products to a higher level. Ordinarily, thickeners of the standard types operate with such a low power consumption and are such relatively inexpensive machines to install that new mills will always be designed to take advantage of these characteristics; centrifugal thickeners could find application only in older mills.

The centrifugal dewatering of thickened material presents a more promising field for the use of this force. Thickened material must usually be filtered at a prohibitive cost, because of the mechanical characteristics of the solids. The "neck of the bottle" in dewatering flotation concentrate has nearly always been in filtering the thickened material.

AMALGAMATORS AND CONCENTRATORS

Centrifugal amalgamators doubtless have an excuse for existence. By the use of centrifugal force very small particles of gold and platinum, which tend to be wafted away by the water streams in which they are suspended, could be forced to come in contact with a live surface of quicksilver; and those that refuse to amalgamate would sink in the quicksilver because of their higher specific gravity. Several machines for this purpose have been invented; and, although they have found little use, there seems to be no reason why a successful machine should not soon be forthcoming, designed for continuous feed of pulp and continuous discharge of tailing, but not necessarily arranged to insure a continuous discharge of the precious metal, amalgam and mercury.

Centrifugal concentrators have been the dream of inventors ever since it was recognized that there was a problem in treating the slime formed in ore dressing. Flotation has given an answer in regard to most of the sulphide ores and metallic minerals, and to some extent for oxidized ores; but in general it may be stated that the true slime in oxidized ore needs gravity-concentration treatment. Large sums of money have been spent in developing centrifugal concentrators, several of which have been or are near to becoming successful machines. An alternative to flotation would be welcomed in some quarters, for technical and business reasons; and it is to be hoped that successful developments will take place along these lines.

*By permission of the Director, Bureau of Mines, Department of the Interior.



Separation

Solids From Gases

RECENTLY a request for an estimate on a definite proposition of separating solids from gases was sent out to seven reputable manufacturers of equipment in this field. When these estimates were returned quotations were found to vary from \$620 to \$6,500 for the job! What is the plant engineer going to advise when he is called into consultation with the purchasing agent in such a case?

Beyond having a clear conception of the various factors entering into the fundamental process involved, he must know the limitations of the various types of equipment which have possible application in his problem. Otherwise his advice cannot be sound—and and other advice is worse than useless. In the past the difficulty of passing intelligently upon problems of this sort has been increased by the fact that the literature has contained very little connected and satisfactory information on the subject.

Where does the necessity for the use of an air or gas filter exist? Within what limits may any such device operate? What are the specific applications of various types to various fields? Above all, what type is most economical to use for a given operation? M. I. Dorfman here answers these questions in a fair-minded manner which clarifies the situation without at the same time smacking of text book lore.

The general problem of solids from gas separation demands solution in many industries. In each of these, different complicating factors enter. Usually one of three reasons gives rise to the problem—to rid air of solid matter for the purpose of safeguarding the health of workmen, to clean air or gas for the purpose of manufacture, or to clean these media because the suspended solid is valuable. Settling chambers, spray chambers, bag rooms—these are employed more generally than the most modern apparatus and hence are better understood both as regards utility and operation.

Two significant developments seem to us to be that of the automatic bag house and that of the Cottrell process. For that reason we are to present in an early issue an article by P. E. Landolt, an engineer thoroughly familiar with the recent remarkable developments in the field of electrical precipitation. For the same reason, an article on the development and application of the automatic bag house is here included by F. L. Jorgensen, president of the Dust Recovery Corporation.

What is necessary above all else in dealing with this problem is sincere co-operation among prospective users of equipment, actual plant operators and the equipment makers. Because it is empirical, no one has a better opportunity to give sound advice than those who are installing or using similar equipment.

Surveying the Possibilities in Mechanical Gas-Solids Separation

A Summary of Existing Types of Apparatus, Including Limitations, Specific Application and General Hints on Solution of Problems

BY M. I. DORFAN

Allis-Chalmers Co., New York City

IT WOULD be to the operator's benefit to realize that each dust-collecting problem that exists is distinct in itself—that is, each problem requires the attention of the numerous specialists. The operator must be careful in examining the various devices that are offered him to determine exactly what type will bring about for his operations the best results. Dust-collecting problems may sometimes be handled by any one of these devices, but as a rule they resolve themselves into solution by only one particular machine.

The basic necessity for the use of a filter type dust collector grows out of the collecting limitations of other devices. Where settling cham-

bers, cyclones, washers, electrical precipitators, etc., do not give the required efficiency and where it is desirable and practicable to collect dusts or fume in a dry state, filter type machines are used.

However, there are certain basic limitations that encompass the use of these devices. Briefly stated, they are as follows: the temperature of the gases entering the machine, the moisture quality of the gases as well as of the entrained material, the physical characteristics of the material to be collected and the chemical characteristics of the gases and dust to be handled.

For ordinary purposes fabrics made of cotton, linen, wool, or mix-

tures thereof, are used for the filtering medium. Actual operation has shown that these cloths begin to lose their strength within the following ranges: Cotton cloth at 210 deg. F., wool cloth at 270 deg. F.

In collecting dusts which have certain heat-insulating qualities it has been found that gases of slightly higher temperature may be admitted

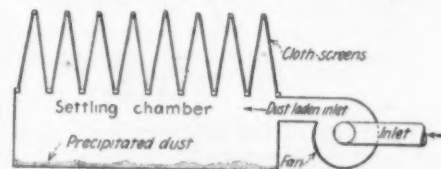


FIG. 1—SCREEN TYPE DUST COLLECTOR (PRESSURE)

to the dust collectors, but when the cloth itself reaches temperatures indicated, disintegration usually begins to set in and manifests itself first in the form of a charring of the filter medium. It is true also that an excessive acidic or alkaline condition of the gases, which carry the dust, especially in the presence of moisture, frequently tend to destroy or to impair the usefulness of filter cloth.



The simplest form of filtering equipment is shown in Fig. 1. It consists of nothing more than an ordinary settling chamber, over the top of which there is provided a series of cloth screens. These cloth screens tightly inclose the settling chamber, so that all gases that leave

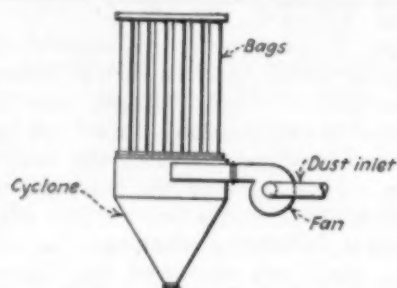


FIG. 2—COMBINATION FILTER CYCLONE (PRESSURE)

this settling chamber must pass through the screens. The dust-laden air which enters at the inlet is first subjected to the action of gravity and reduced velocity for primary dust settling. The gases then pass through the cloth screens. The dust is retained on the inside of the screens and the cleaned air or gases are dissipated to the atmosphere.

Figs. 2 and 3 show a little further development of the idea used in this first-mentioned kind of collector. Here a cyclone or centrifugal separa-

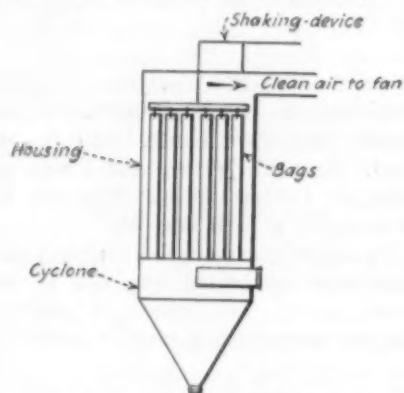


FIG. 3—COMBINATION FILTER CYCLONE (SUCTION)

tor is used as the preliminary means of collecting and bags are used as a secondary or final means. This type of machine is frequently provided with some means for external hand or mechanical shaking for cleaning of the filter medium.

A recent well-developed type machine is shown in Fig. 4. The dust-laden air is drawn or blown into a dust chamber through a pipe as indicated by arrows, and is either exhausted from or blown to the chamber at the right. As the air passes through the screens it comes into the chamber at the right, clean.

The dust settles in the hoppers and on the screens, and the screens are then mechanically agitated at frequent intervals during the day. This action is intended to clean the screens and deposit the dust in the hoppers for convenient handling.

The machine which is shown in Fig. 5 operates as follows: It is usually attached to the ceiling or other suitable support. There is a series of cloth tubes opened at both ends securely fastened to header sheets forming the parts of both upper and lower case. In the lower case there is also provided a series of drags or conveyors. With the machine in operation an opening is made in either side or end of the upper case to receive the dust-laden air. This dust-laden air enters the cloth tubes in a downward course and is rapidly exhausted through the meshes of the cloth. The air expands as it enters the machine and in so doing passes into the tubes with a decreased or lessened velocity.

The dust falls by gravity into the lower case. This action is assisted by the cleaning device at the side, which is a frame that is moved vertically to assist in freeing the dust from the cloth. From the lower case the dust is discharged by a drag into a cross-conveyor at the end of the machine, from which it is then discharged from the machine.

GRAIN CLEANING DONE IN SPECIAL TYPE

Another type of machine which is quite generally used in grain cleaning and flour mill practice is shown by Fig. 6. The dust-laden air enters the machine at the top of the casing and passes into the annular space surrounding the cloth tubes. It is within this space that the velocity of the air carrying the dust is reduced and consequently a large portion of the dust and particularly the heavy particles drop to the bottom conveyors.

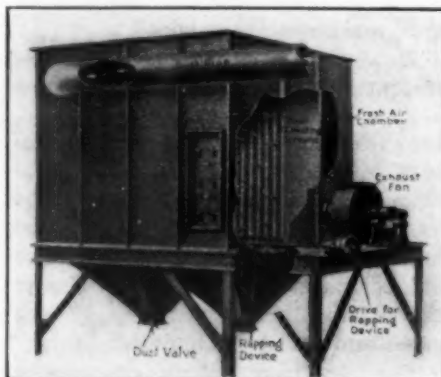


FIG. 4—PLATE TYPE BOX FILTER



FIG. 5—TUBULAR BAG TYPE FILTER

The air which carries the fine dust enters the slowly revolving drum which carries the cloth tubes. As this drum revolves it finally reaches a "dead air" chamber. Here the tubes are collapsed by a reverse air current connected to the inlet of the fan. The dust is also loosened from the tubes by a series of rappings from iron hammers. This causes the dust to fall into the upper conveyor.



FIG. 6—ROTARY CLOTH TUBE DUST COLLECTOR

This last operation occurs when the small or closed ends of the tubes are at the top—that is, when the tubes are directly over the upper conveyor.

Fig. 7 illustrates the manner of operation of one highly developed form of pneumatic filter. A single compartment with its cleaning mechanism is shown.

How should the operator be guided in the selection of the proper type of filter for his problem when there is such a diversity of types and consequently of prices for the various apparatus as outlined above?

In the first place, all dust collectors have a certain back pressure. This occurs because the air passing through these collectors contends with the following conditions: Skin

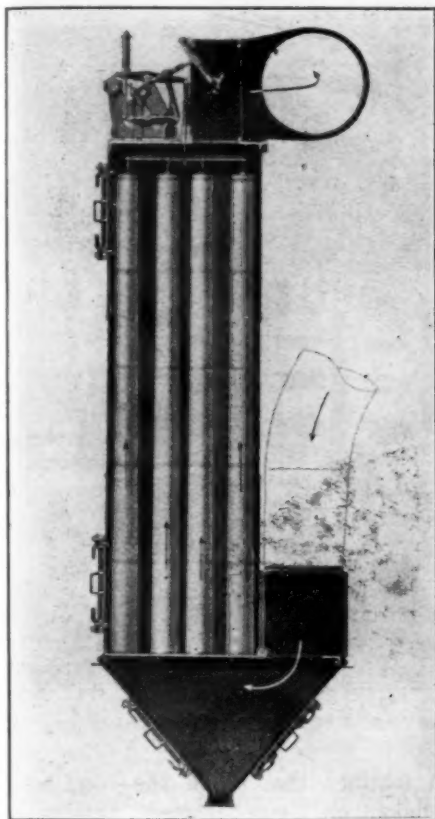


FIG. 7—CROSS-SECTION OF PNEUMATIC FILTER

friction, change in direction, changes in velocity, resistance created by passing through cloth, and, resistance created by passing through dust deposited on cloth.

Now, since most dust-collecting systems have as their prime moving agent a centrifugal fan and the characteristics of these fans are such that the volume of air that the fan will handle at a certain speed depends on the resistance or back pressure against which this fan must operate, therefore it is obvious that the operator must first determine the volume of air required for the problem and also ascertain the necessity for keeping the air volume constant.

For simple problems, such as one in which a comparatively small volume of air is handled and in which air carries with it dust of varying degrees of fineness, of such a nature that it can be largely precipitated in either a cyclone or settling chamber, with only a very small amount of the fine dust going over to the screens or bags, dust collectors similar to the type shown in Figs. 1 to 3 may be used. These machines require frequent manual cleaning.

These machines should not be used in connection with any dust which has "packing," non-porous qualities. For materials similar to sand, which is easily precipitated and removed from cloth and under conditions mentioned above, these devices may well be used.

When fine dusts encountered are of such a nature that they must be filtered and cannot be handled in settling chambers, etc. machines of the types shown in Figs. 4 and 5 may be used. These machines are cleaned intermittently, with the result that the "gas volumetrical condition" of the system of which they form a part is always a varying factor. When the screens have been cleaned, the maximum air volume is handled and as the material deposits on the screens the back pressure increases and therefore the volume drops off. These machines are sometimes installed in duplicate units to permit continuity of operation especially where it is not practical to shut down the system entirely in order to clean out the collecting unit. As a rule the initial back pressure in these machines is not very high, due to the fact that they have a comparatively large cloth area.

Recovery of Fine Solids From Air and Gases by Suction Filters

BY F. L. JORGENSEN

President, Dust Recovering & Conveying Co., Cleveland, Ohio

MANY changes, developments and improvements have been made in all industries in late years and much attention has been given to the reclaiming of waste products as well as the increasing of efficiency of machine and human operation. To increase the efficiency of the human elements it has become more and more apparent and clear to the industrial operator that the improvement of sanitary conditions, ventilation, light, cleanliness, temperature, etc., increases directly the human efficiency, reduces labor turnover, improves products, etc., and in most industries this has brought about a study of ways and means to prevent floating dust from becoming a nuisance.

Many machine operations (especially grinding) have been improved and made more efficient by a proper application of dust-collecting equipment in direct connection with the grinding machines. Valuable extremely fine dust is saved which otherwise would be wasted. The

biggest percentage of all materials handled in all industrial operations are highly explosive when they are in an extremely fine state and mixed with the critical air volume; dust-collecting and dust-preventing developments have assumed a highly important place on this account.

The reclaiming of solids from stack gases, of course, has been carried on for many years in the smelting field, where oxides of various kinds have been collected. This field, however, in the writer's opinion, will gradually extend to many smaller smelting operations—for instance, brass foundries. Solids have also been separated from blast-furnace gases with the object of getting clean gas, so that scoring of cylinders in the gas engines, where the gas is often used for power, is prevented.

It is proposed here to concentrate on generalities and to pick out only a few examples of modern installations for description. Assuming that the older equipments as used for dust-collecting purposes for many

years are already known to most of the readers that are interested in this subject, we shall only mention the older methods in passing.

Before going into details of air filtration, a highly modern system should be mentioned—namely, the electrical precipitation method—which without doubt has filled a great need, especially in the smelting field, where gases of high acid content have to be cleaned. In this field either the electrical precipitation process or filtration through cloth is used entirely. The acid content, temperature and moisture conditions will determine which method is the best and most logical to use.

One of the newest developments is the suction filtration method, which in late years has gained in favor and consequent commercial application on account of great improvements on some otherwise old ideas that originated in Germany. In reality, suction filters are improved bag houses. With pneumatic equipment for cleaning the bags and with the bags maintained in a clean condition at all times, a constant resistance to air is obtained and much denser filter cloth can be used than is possible in the old-fashioned standard bag houses. Then, too, a



much smaller filter cloth surface is required; in general only from 10 to 20 per cent of the bag house cloth surface is required for the same gas or air volume. Fire risk is eliminated, as in general only one or two compartments, as shown in Fig. 4, can burn at one time. Explosive risks are greatly minimized or entirely eliminated. Unsanitary and dirty conditions which are usually unavoidable when bag houses are used are eliminated.

When using the term "bag house" we understand the larger houses used in large smelting operations as well as the miniature installations in plants where a small fan blows dust-laden air into a few smaller suspended bags.

The suction filters consist, as Fig. 1 indicates, of two or more cylindrical filter compartments made of sheet steel. Inside of each of these compartments are suspended a number of cylindrical bags open at the bottom, where they are fastened to collars over openings in a bottom plate. At the top they are closed and fastened to a cover, or plug, which again is suspended from a frame to which a rod is fastened and extends up through the top plate.

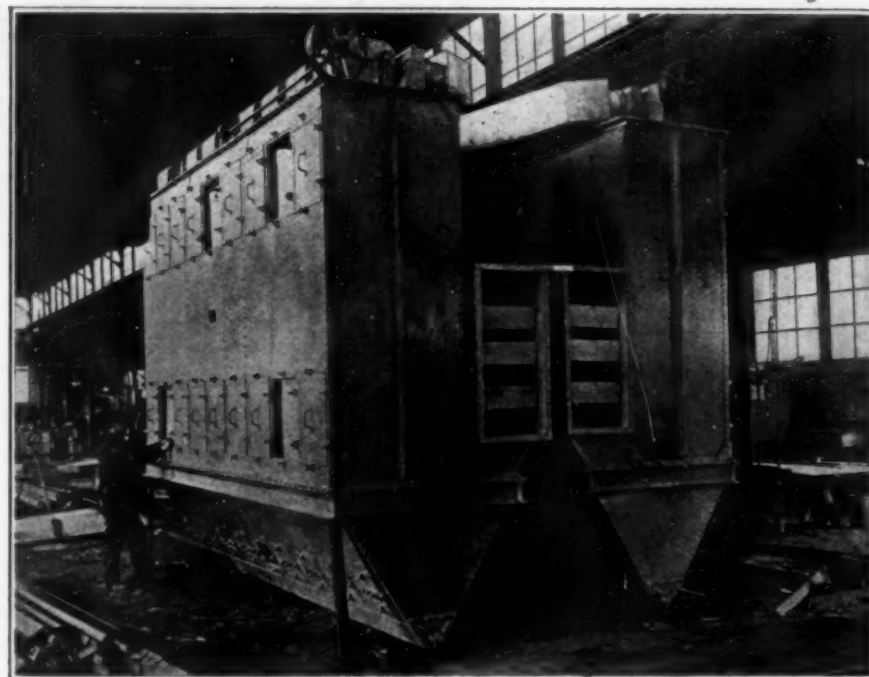


FIG. 2—SQUARE BOX DEVELOPMENT OF TYPE SHOWN IN FIG. 3

This rod connects either to a piston in a pneumatic cylinder or to a cam-shaking mechanism. A special outlet valve for the filtered gas or air is provided on the top plate, and in this valve a gate is arranged in such

a manner that when the bags are shaken on a compartment, this gate closes over the suction from the fan and opens for the outside air, which is sucked in by the vacuum in the other compartments, thus creating a reverse air current, which, together with the effective shaking, thoroughly cleans the bag, the collected dust falling to the dust hopper or bins below.

Each compartment is at predetermined periods shunted off by a specially built timing device and cleaned; this operation goes on in rotation. The period is determined according to the kind of dust, quantity, etc., being handled. Cleaning may take place as often as every 2 or 3 minutes, or as seldom as every hour or two. The cleaning of each compartment with the pneumatic method takes only 3 to 4 seconds, while with the mechanical shaking methods it takes several minutes.

It must be noted that the fan draws the air through the filter, which is placed between fan and dust source. The fan therefore always handles clean air; which explains why all explosions occurring in fans are likely to be avoided if suction filtration methods are used. In bag houses and most other systems the fan handles the dust-laden air and blows into the dust-collecting equipment.

It will be of interest here to note the construction of some of the earliest equipment of the suction

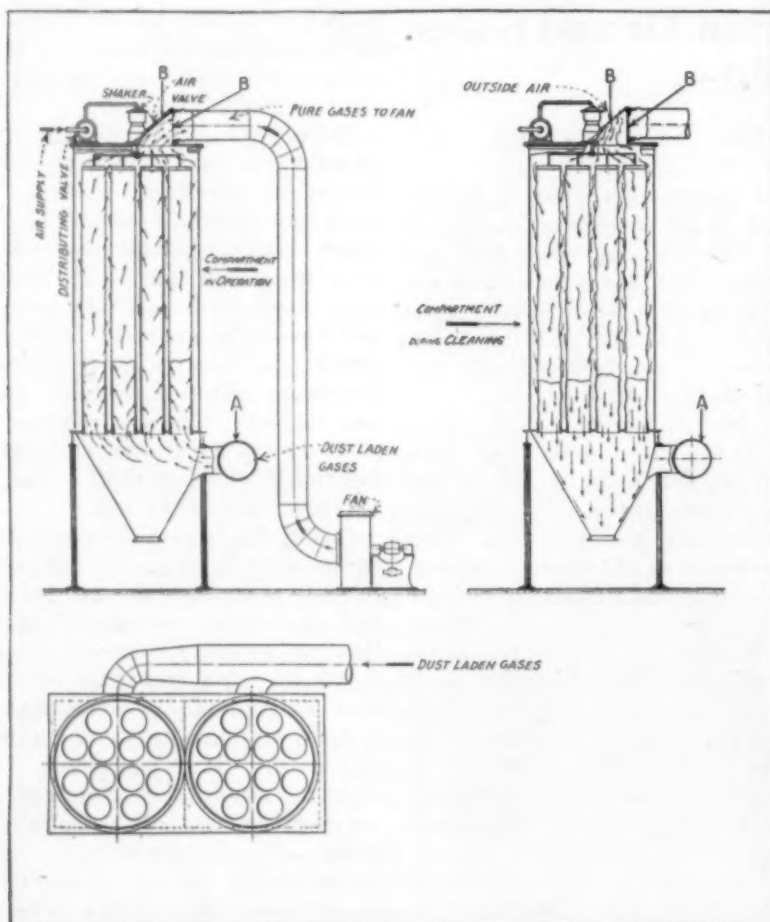


FIG. 1—SKETCH SHOWING SUCTION FILTER IN OPERATION

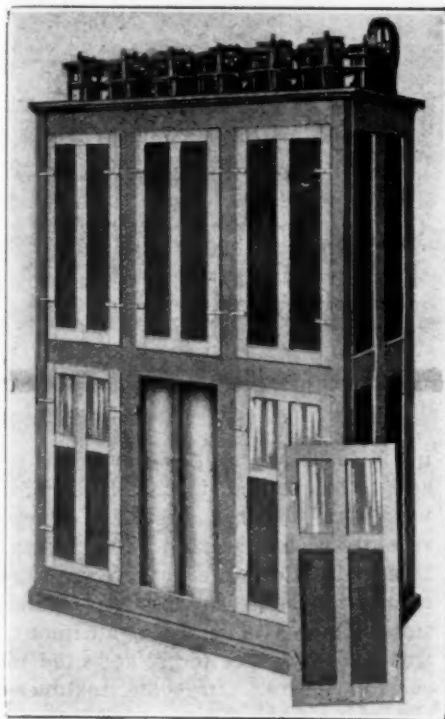


FIG. 3—OLD STYLE BOXED FILTER WITH CAM SHAKER

filter type. Fig. 3 shows a very old machine build of wood and having a complicated cam-shaking mechanism, while Fig. 2 shows equipment based on the same idea, but made of steel and built at a later period. In Fig. 2 each of the large square boxes shown is divided into separate compartments. As the machines are under vacuum, heavy plates had to be used, and as each equipment had to be either assembled in shop or riveted together in place of use, it is apparent that the cost was excessive and that it was difficult to place this equipment in the inaccessible places that often must be used. Certain other defects were present with this equipment—for instance, one compartment could not be disconnected

for repairs without stopping the whole unit, and it was only after cylindrical units were designed that these defects were overcome to a considerable extent. These defects in the cylindrical units have been largely eliminated, and extensive experience gained with a large number of these filters handling various materials under various conditions has resulted in the installation of several thousand suction filters now in operation in the States.

Suction filters are made to suit any air or gas volume, for temperatures as high as cloth will stand (not over 250 deg. F. should be allowed). All dry air or gas not containing a too high percentage of SO_2 or SO_3 can be successfully filtered. If gas is too high in temperature, it must be cooled. If gas

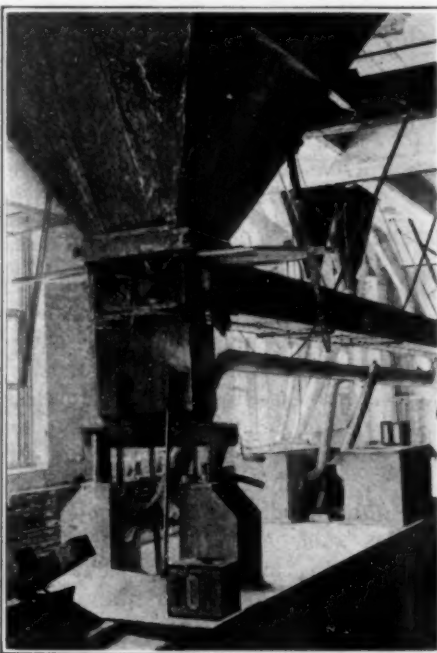


FIG. 5—DUST DELIVERY IN PACKING ROOM OF INSECTICIDE PLANT

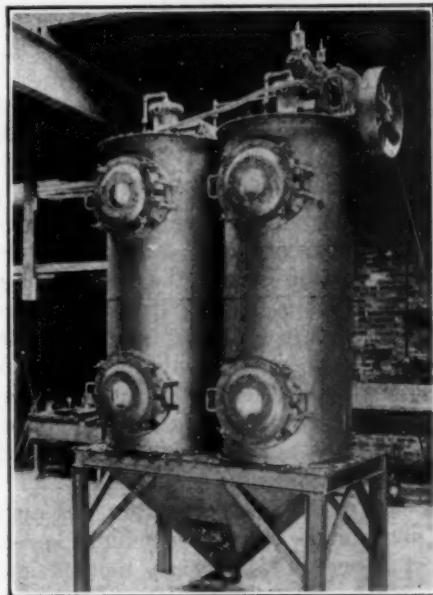


FIG. 4—TWO-COMPARTMENT CYLINDRICAL FILTER OF MODERN CONSTRUCTION

contains moisture (for instance, gas from driers), arrangements must be made to insure that the temperature is above condensation point. This is all taken care of by careful engineering and it has been recognized that dust collecting is primarily a problem of chemical engineering of the first order.

Fig. 4 shows a very small two-compartment filter of modern design. The picture shows the standard of size and fabrication that modern conditions have started to require. This picture also shows the equipment that regulates the cleaning periods. Similar apparatus to this has been used to a considerable extent in elimination of such poisonous gases as those carrying volatilized arsenate of lead or lime. Fig. 5 shows suction pipes and hoods in the packing room of such a plant. Cleanliness is quite



FIG. 6—GRINDING ROOM IN COAL PLANT

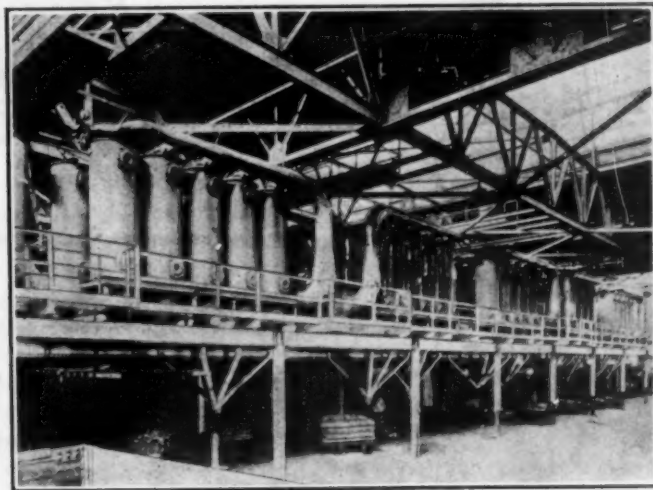


FIG. 7—PART OF A SEPARATING INSTALLATION



Leaching and Extraction

PERHAPS there are more diverse problems grouped under this head than under any other unit process. Imagine on the one hand the extraction of tanning materials from the various barks, and on the other the leaching of a soluble constituent from a furnace roast. Then again there is the extraction of a dissolved product from one solvent by another, and finally the metallurgical problems of heap leaching of low-grade ore.

In treating this subject we have published the first

part of an article by A. W. Allen, assistant editor of *Chem. & Met.*, on the fundamentals of gravity leaching. In this article are discussed the principles of good leaching. The second article, by Mr. Shafor, describes the leaching of sugar from sugar beets, a problem that has called into play some of the most ingenious chemical engineering in industry. Familiarity with modern industrial practice is nearly the only way to acquire a knowledge of this unit process and we shall continue our efforts along these lines.

Fundamentals of Gravity Leaching

Some General Principles Developed in Metallurgical Practice Which Offer Constructive Suggestions to Chemical Engineers Confronted With Leaching Problems

BY A. W. ALLEN

Assistant Editor, *Chem. & Met.*

A CLEAR CONCEPTION of the meaning and scope of technical terms in common use permits a rough classification of industrial processes. Percolation infers the passage of a liquid through the interstices of a mass. Leaching is the process of extracting soluble matter by percolation. In chemical and chemicometallurgical processes of extraction, percolation and leaching may and usually do occur simultaneously. Percolation is usually hastened by the application of pressure or vacuum. Leaching may be improved by modifying the physical or chemical character of the solvent.

RELATION BETWEEN PERCOLATION AND FILTRATION

The difference between pressure and vacuum filtration on the one hand and the so-called gravity percolation on the other is not so distinct as might be inferred. Work is done in both instances, and work involves power. With a pressure filter, a definite pressure must be reached and maintained; with a vacuum filter, atmospheric conditions must be nullified; with a percolator the leach liquor must be raised above the level of the bed of material through which it is to percolate. This gravity head, secured by the expenditure of power, permits the passage of solution through the interstices between the particles comprising the mass. Other conditions being equal, the resistance to flow depends on the fineness of the

material. The practicability of adequate drainage usually determines the feasibility of gravity leaching, although final dewatering may be effected by the application of a vacuum underneath the bottom support. Percolation may be possible through a depth of 4 ft. of crushed ore, but impossible through a depth of 8 ft. of the same material. To counteract the resistance to flow it may be feasible to increase the pressure of the percolating solution by the maintenance of a definite height of liquor above the surface of the mass. But this modification is usually impracticable under ordinary circumstances.

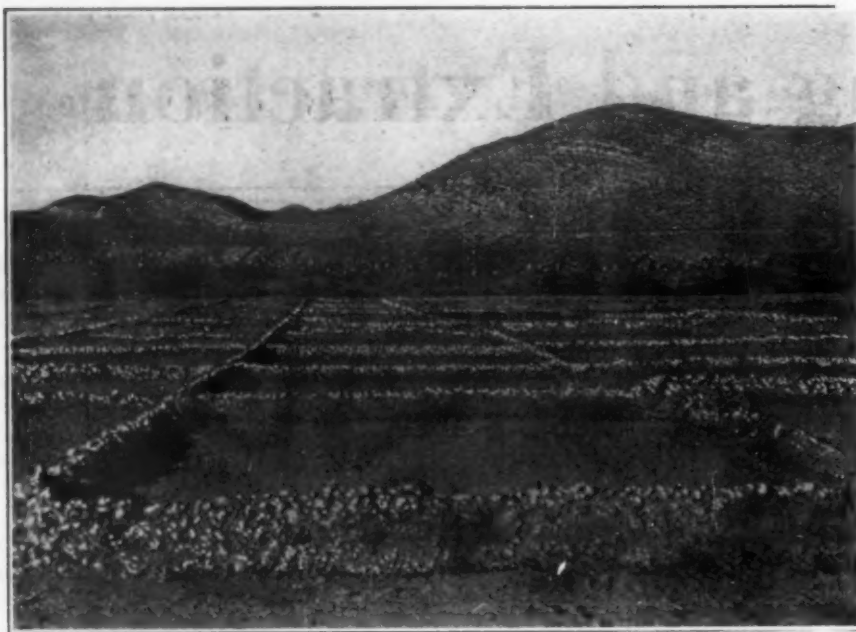
The final phase of operations is the separation of liquid from solid; a vacuum may be of service to remove the last traces of residual moisture, but it is undesirable to apply it underneath the bottom support if the resistance is too great.

Percolation may be performed by one of a number of methods, which may be grouped under two heads, depending on whether or not the material to be leached is submerged in the circulating solution or other liquid. Non-submergence leaching processes are capable of further subdivision, according to whether or not the material is inclosed, or whether a bottom support, natural or artificial, comprises the essential apparatus on which the charge can rest and by means of which the effluent liquor can be collected.

Heap leaching of copper ores was being practiced in the middle of the eighteenth century, so far as records show; but it is not a process the introduction of which can be associated with a definite date. It is recorded that in Spain the heaps of ore at Rio Tinto were leached with water, the copper in the sulphate resulting being recovered by precipitation with iron. More recent practice indicates the introduction of minor refinements. The bed is prepared and hardened. Culverts, made of large pieces of ore, are arranged longitudinally, with intervening cross-culverts, to insure efficient drainage toward a sump. The ore is roughly graded as to size, and distributed so that the larger pieces form a bed for the finer material. The surface of the heap is divided into large, shallow depressions.

The heap-leaching dump below the Copper Queen concentrator of the Phelps-Dodge Corporation, near Bisbee, Ariz., is an example of modern practice. It is estimated that the ore treated thus will contain but 0.75 per cent copper; so the commercial success of operations should indicate the scope of an important phase of leaching practice. About 500,000 tons of low-grade ore from Sacramento Hill will constitute the first "charge." No crushing will be necessary; the larger lumps are to be used for culverts and flues. The proper distribution of the ore is important, and an even percolation over the entire area is necessary to secure efficient results. A total extraction of about 70 per cent is expected after a leaching period extending over 6 years.

Tests have shown that percolating solutions can penetrate large pieces of ore of this type, especially if a



HEAP-LEACHING DUMP AT COPPER QUEEN CONCENTRATOR

protracted time for leaching be allowed. The conditions, therefore, are favorable for the dissolution of the copper, but they are unfavorable for the replacement of the solution with weak washes or water. During the many intervals between active leaching it is probable that, on exposure of the lumps to the air that circulates through the charge, a superficial efflorescence of copper salts occurs, resulting in a local concentration of "values." This incrustation is dissolved during subsequent washings, whereupon capillarity again takes place and more crystals are formed. The total amount of copper extracted is comparatively low, because of the difficulty of efficiently replacing that which has been dissolved in the interior of the lump. This disadvantage, counteracted to a considerable extent by cheapness of operation, is the principal drawback to the non-submergence method of heap leaching.

FUNDAMENTALS OF BULK LEACHING

The failure to leach by gravity has been due in many cases to a neglect of fundamental requirements. A primary essential is that the physical characteristics of the material in all parts of the charge shall be uniform. In cases where the raw material is drawn from several deposits of varying soluble content and containing variable proportions of fine—a condition that is characteristic of operations on the Chilean nitrate pampa—the necessity for adequate mixing after crushing cannot be overestimated or overstressed. In

large-scale operations, an efficient system of blending, and arrangements whereby segregation in the vat of any appreciable bulk of material of abnormal physical characteristics, call for expert engineering advice and the benefit of those experienced in the problems incidental to the mechanical handling of material.

Provision must be made for the even distribution of fine material prior to submergence and for its maintenance during leaching. This factor has not been recognized in the Shanks process; it was disregarded by some of the investigators of the hyposulphite process. An author of

a book on the lixiviation of silver ores, published in 1895, describes an experiment thus: "Five and a half tons of this ore were crushed . . . through a No. 30 screen, and charged into an ore tank, filling the latter to a depth of 14 in. The tank had been previously filled with 36 in. of extra-solution containing 1 per cent of bluestone and 2.25 per cent hyposulphite. It was found that the solution would not filter." And no wonder! Leaching was impracticable under the conditions observed; but there is nothing to show that it was economically impossible. When the raw ore was tipped into the solution, the coarser particles fell to the bottom, forming a bed for the finer particles, which, in turn, supported the slime. The filtration of any appreciable thickness of clay without even a moderate amount of pressure or vacuum is impossible; but, had the original distribution of fine material in the charge been maintained, it is possible that percolation of leach solution by gravity might have yielded satisfactory results; under such conditions, gravity leaching has been practiced successfully elsewhere. The results might have been a failure whatever procedure was adopted; ores vary widely in physical characteristics. The point that needs emphasis is that, in attempting to apply a simple process, the fundamental factors governing successful operation were ignored. A more extended discussion of these factors as well as those governing vat leaching will be published in a subsequent issue.

Diffusion Process in Beet-Sugar Industry

How the Principles of Counter-Current Extraction Are Applied in Recovering Sugar From the Cells of the Sugar Beet

BY R. W. SHAFOR

Superintendent, Research Laboratory, Great Western Sugar Co., Denver, Colo.

THE diffusion process of Robert dates back to 1848 and since that time has become the standard method for extracting sugar from the beet. As operated today, it performs two functions: first, the extraction of the sugar, and second, the "elimination" of a small portion of the non-sugars present in the beet juice. ("Elimination" is a term used to express the removal of impurities, by precipitation or otherwise, from the sugar solutions during the process of beet-sugar manufacture.) In other words, it has become, in addition to the primary extraction step in the

process, a factor in the purification of the sugar solutions.

The sugar beet root is prepared for the diffusion process by carefully separating foreign substances such as beet tops, weeds, rocks, etc., and by further washing to free it from soil. Following this it is sliced into cossettes. To give a rough idea of the average cossette, it has a length of 4 or 5 in. and a V-shaped cross-section, the legs of the V being approximately $\frac{1}{8}$ in. in length and $\frac{1}{8}$ in. in thickness. The production of this V-shaped cross-section, together with a smooth surface, is essential and re-



quires that close attention be given to the removal of foreign materials, to the maintenance of well-sharpened slicing knives and to their proper alignment in the "slicer." The slicers in general use are of two general designs; in one the knives are mounted on the peripheral face of a rotating drum, the axis of which lies in a horizontal plane; in the other they are mounted radially on a circular disk which revolves in a horizontal plane.

The apparatus employed in the diffusion process proper, termed a "diffusion battery," is usually made up of a total of fourteen units known to the industry as "battery cells." Fig. 1 illustrates a vertical cross-section of a typical cell unit, the horizontal cross-section being circular. The cubical content of each cell depends, of course, upon the quantity of beets to be worked per hour, and where this amounts to from 50 to 60 tons, will be from 200 to 250 cu.ft. The charge of sliced beets for such a cell will weigh from 4 to 4.5 tons. Charging is effected through the top door, the exhausted cossettes being discharged through the bottom door as indicated in the sketch. These operations are controlled from a floor located at an elevation approximately 2 ft. below the top of the cell. When the cell is in operation the diffusion juice enters through the inlet port at the top, percolates downward through the cossettes, passing through the perforated plates at the bottom, and leaves the cell through the outlet port.

Chains are suspended from the walls of the cell so as to form baskets. These serve to carry a large portion of the weight of the charge which, but for their presence, would rest entirely on the perforated plate, thus increasing the resistance both to the percolation of the diffusion juice through the charge and its passing through the plate perforations. They likewise assist in avoiding channeling or short circuiting with its resultant lowering of extraction.

OPERATION OF DIFFUSION BATTERY

Fig. 2 illustrates, diagrammatically, the arrangement of the cells in the battery, together with the accompanying juice heaters required for temperature control. The heat is controlled through the indirect application of steam. It hardly seems necessary to discuss the method of operation further than to point out

that from a basic viewpoint it is practically identical with the counter-current leaching so widely used in chemical industry. It will be noted that cell 14 is being charged with fresh cossettes while exhausted cossettes are being discharged from cell 13, a given quantity of "diffusion juice" (solution containing beet juice solutes) is being drawn from cell 1 and a given quantity of water introduced into cell 12. When these operations are completed, cell 12 will be cut out of the system, the water introduced into cell 11, the solution from cell 1 will be introduced into the bottom of cell 14 and allowed to rise through the freshly charged cossettes until all of the air has been displaced, at which time its direction of flow will be reversed and the operations mentioned above repeated.

The diffusion process is one of the more important steps in the process of beet sugar manufacture and in spite of its having been employed during the last 75 years, it would still appear to comprise a fertile field of investigation.

The cossettes are usually conveyed from the slicing station by a single conveyor belt, from which they may be discharged into any one of the battery cells at will. The exhausted cossettes are discharged into a pit below the battery, from which they are removed by pumps.

CELL STRUCTURE SHOULD REMAIN INTACT

Considering the diffusion process from an extraction standpoint, the microscopic structure of the sugar beet is of primary importance. The beet root is made up of small plant cells in which sugar, in solution, is stored. During the above-mentioned slicing procedure the walls of a portion, possibly 5 per cent, of these small cells is ruptured by cutting. Another portion is ruptured due to pressure and distortion during the passage of the knives through adjacent cells. In good slicing practice by far the larger portion remain intact as they enter the diffusion apparatus.

The walls of these small plant cells are composed of two distinct layers, the outer of which is generally considered to be a porous cellulose membrane on which is supported an inner layer of protoplasm. In cells un-

injured during slicing, this protoplasm enters the diffusion apparatus as a membrane impermeable to sucrose. However, this membrane breaks down, possibly coagulates, when its temperature is raised to approximately 50 deg. C., allowing the sugar to diffuse readily through the outer cellulose wall.

Thus the diffusion process, since the extraction of sugar from the plant cell is not accompanied by dissolution phenomena, would appear to be a function of the physical chemistry laws governing the diffusion of solutes through porous membranes. Although certain factors which are recognized as entering into these laws, such as temperature, area and length of diffusion path and concentration difference, are generally accepted and employed by operators as means of control, so little is known of the additional factors which enter the consideration that mathematical application remains impractical. It is probable that the "diffusion coefficient" derived by Southerland, Millikan and others (see Bingham's "Fluidity and Plasticity," p. 188, 1922, McGraw-Hill) will prove a clue to the missing link, but this remains to be proved.

The temperature factor thus becomes important from two viewpoints. Before the sugar can be diffused from the cossette, the temperature of the plant cells must be raised to approximately 50 deg. C.

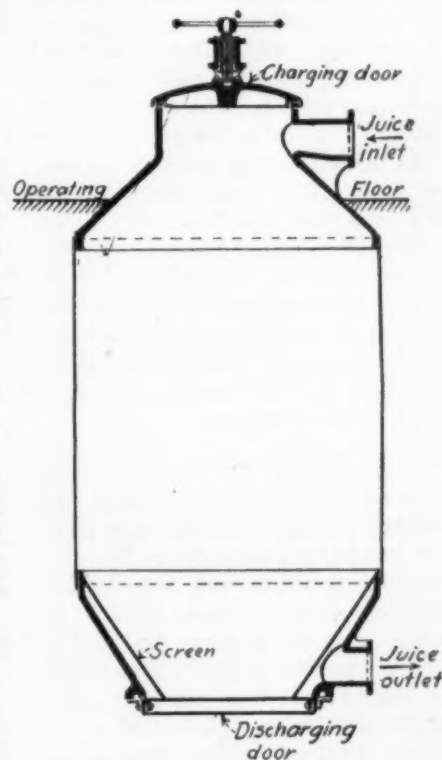


FIG. 1—DIFFUSION BATTERY CELL

for the purpose of breaking down the impermeable protoplasm membrane. Again, other things being equal, the rate of diffusion will be greater as the temperature is increased, thus rendering desirable the highest temperature attainable from a practical viewpoint. The upper limit of the applicable temperature is a function of the ability of the plant cell walls to retain their rigidity and general shape. In general at temperatures above 80 to 85 deg. C., these cell structures soften rapidly and the cossettes "mat" together in a way that offers great resistance to the percolation of the diffusion juice and further cause a material decrease in the area, with a corresponding in-

ing the thickness of the cossettes, which will cause a variation in both the area and length of the diffusion path. The V-shaped cossette is employed largely for the reason that it facilitates the percolation of the diffusion juice over a large portion of the cossette surface. (It will be noted that in case cossettes having a rectangular cross-section were employed, the flat surfaces resting on adjacent surfaces would result in a considerable reduction in area, as well as resistance to flow through the battery cell.) Again, if the surface of the cossette is excessively rough or ragged because of dull slicer knives, the result is a marked decrease in the rate of diffusion. This

tional water introduced into the diffusion battery.

As in the case of the diffusion rates, the laws governing the purification function of the process remain undetermined. To give a quantitative idea of the extent of this "elimination" it may be said that, given a beet the juice from which shows a concentration of 18 parts of non-sugars per 100 parts sugar, the resulting "diffusion juice" (containing extracted solutes) will show 17 parts of impurities per 100 parts sugar under average conditions. That this phenomenon is possibly a function of rates is evidenced by the view held generally among operating men that the more rapidly the diffu-

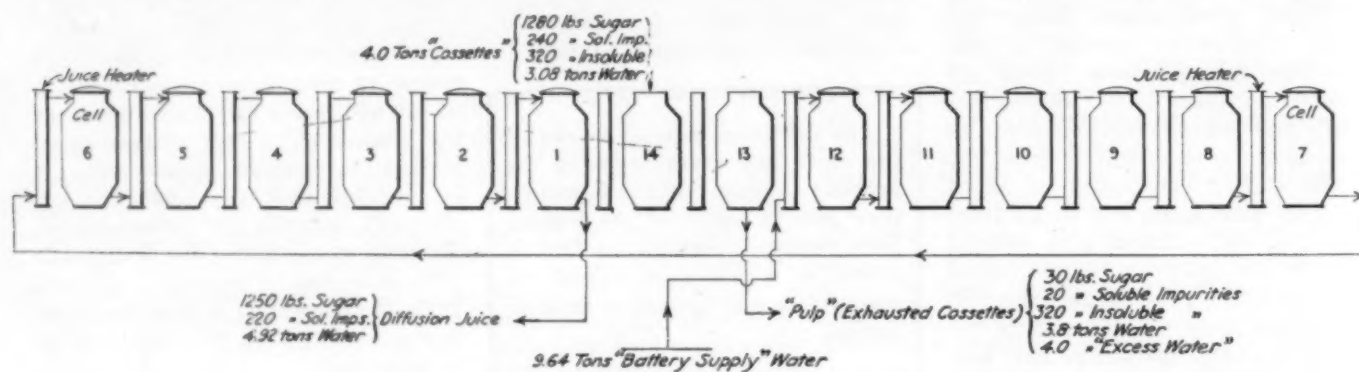


FIG. 2—DIAGRAMMATIC FLOWSHEET OF DIFFUSION BATTERY

crease in the length of the diffusion path. Cossettes produced from well-ripened beets that have not deteriorated during the storage period between harvesting and slicing possess this resistance to a larger degree, but even they will soften if exposed to the temperatures mentioned for too long a period. The curve shown in Fig. 3 illustrates the temperatures of the juice entering the various battery cells. The temperature of the juice entering the first cell is low because of the heat absorbed by the cold cossettes in the first two cells, while beginning with cell 6 the temperature in the last cells of the system is gradually reduced to avoid the effect of the temperature-time factor above mentioned.

WHY COSSETTES ARE V-SHAPED

Other factors being equal, the quantity of sugar diffused in a given time probably varies directly with the mean area of the path of the diffusing sugar molecules and inversely with the distance traveled by the average molecule. Aside from the effect of temperature, these factors are largely controlled at the slicing station. Slicer knives are made adjustable so as to permit vary-

ing the thickness of the cossettes, which will cause a variation in both the area and length of the diffusion path. The V-shaped cossette is employed largely for the reason that it facilitates the percolation of the diffusion juice over a large portion of the cossette surface. (It will be noted that in case cossettes having a rectangular cross-section were employed, the flat surfaces resting on adjacent surfaces would result in a considerable reduction in area, as well as resistance to flow through the battery cell.) Again, if the surface of the cossette is excessively rough or ragged because of dull slicer knives, the result is a marked decrease in the rate of diffusion. This

An increased rate of diffusion is, of course, obtainable by drawing from the battery a diffusion juice of lower sugar concentration, thus increasing the concentration difference. The limit of such a procedure is fixed by the economic balance between the value of the additional extraction or capacity so obtained and the costs of handling and evaporating the addi-

sion operation is performed the greater will be the elimination. Again, it is known that diffusion juice taken from a point in the process so that it contains solutes extracted from beet cells, from which has been exhausted approximately 95 per cent of their original sugar content, will show a higher rate of impurities per 100 parts of sugar than was originally present in the beet juice. Such observations may be considered as indicating the applicability of the viscosity factor employed in the above-mentioned "diffusion coefficient."

The data given on the flow sheet (Fig. 2) may be considered as typical of average results. They are based on the processing of beets containing 16 per cent sugar to produce a diffusion juice containing 11 per cent sugar. The extraction calculates 97 + per cent, which is considered good.

The diffusion process is one of the more important steps in the process of beet sugar manufacture and in spite of its having been employed during the last 75 years, it would still appear to comprise a fertile field of investigation.

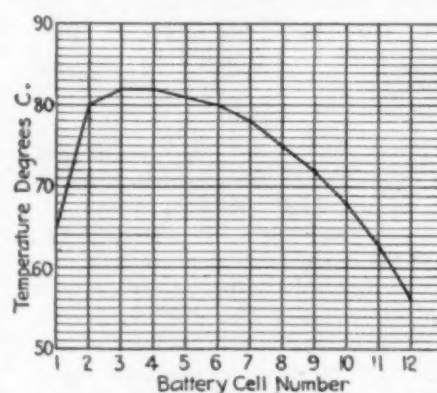


FIG. 3—TEMPERATURE CONTROL CHART



Evaporation

TWO THOUSAND years before the Christian era, our early Egyptian ancestors used direct-heat evaporation in preparing drugs from herbs and roots. Many centuries later—in fact about the year 500—salt and sugar solutions were evaporated over the open fire in simple but nevertheless special apparatus. It is a long jump from the sixth century to the first multiple effects of Pecqueur in 1829 and the horizontal and vertical tube apparatus of Rillieux and Robert in 1845, yet according to one well-known authority all modern evaporators are based on the fundamental types of equipment thus set down almost a hundred years ago.

From this brief historical background it is obvious that chemical engineering as such can scarcely lay claim to the development of the unit process of evaporation. Rather it has been the chemical engineer's privilege to build on a foundation already long standing. To be sure, he has established underlying principles and successfully applied them with increasing efficiency in an

ever-widening field in our industries. But even today, evaporator design is one of the most perplexing problems that face the man who is responsible for production. There can be no simple rule to apply in selecting the evaporator for the special use and, unfortunately, too many chemical engineers have found this out to their sorrow. This suggests the theme for our present approach to the subject—i.e., the all importance of studying evaporator design.

Prof. W. L. Badger, who has already made many notable contributions to this subject in the important series of articles which we have published over the past 3 years, has prepared an excellent review of modern types of evaporators. While he himself would be the last one to admit that his present brief treatment gives sufficient data on which to select an evaporator for a specialized use, still we believe it forms an excellent background for more intensive study. It is a point of departure for the men who want to get in closer touch with the basic principles of this process.

Modern Types of Evaporators

Some of the Fundamentals of Evaporator Design and Construction— Their Relation to Performance in Various Industrial Applications

BY W. L. BADGER

Director, Evaporator Experiment Station, University of Michigan,
Ann Arbor, Mich.

LIKE all engineering problems, the design of an evaporator is a compromise between the best theory on one hand and actual costs of installation and operation on the other hand. Capacity must be high, but first cost and repairs low. High capacity means a high rate of heat transfer; and to get a high rate of heat transfer one is tempted to add various refinements. Up to a certain point they pay; beyond that point they increase first cost, labor costs for operating, and repairs, more than is justified. Where this point of equilibrium between the tendency to complicate and the tendency to simplify will come can be decided only by the judgment and experience of the designer. Further, changing labor and installation costs will vary this relation from time to time, so that there never is any "best" evaporator construction.

In this balance, then, of simplicity against capacity, it is desirable to

analyze the situation further. Simplicity of design can hardly be separated into individual factors; but capacity, which is directly proportional to heat transfer coefficient, can be. In the first place, it is assumed that the reader is familiar with the idea that all the thermal resistance is in two fluid films, one on either side of the heating surface. The nature and thickness of the metal are of slight significance. But what factors limit this film resistance to a minimum?

Many factors which affect the rate of heat transfer are determined by the nature of the material handled and are not variable. Those in the control of the designer are:

On the liquid side

- (a) Velocity of circulation.
- (b) Formation or removal of scale.
- (c) Hydrostatic head.
- (d) Diameter of tubes.

On the steam side

- (e) Velocity of steam.
- (f) Drainage of condensate.
- (g) Removal of non-condensable gases.

The various designs of evaporators

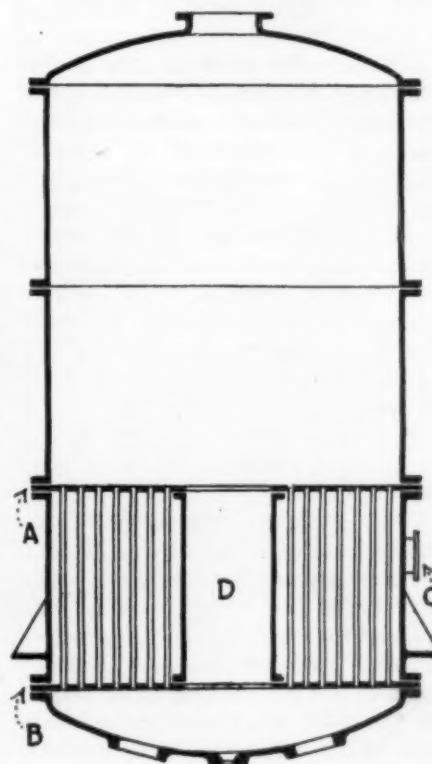


FIG. 1—STANDARD VERTICAL
TUBE EVAPORATOR

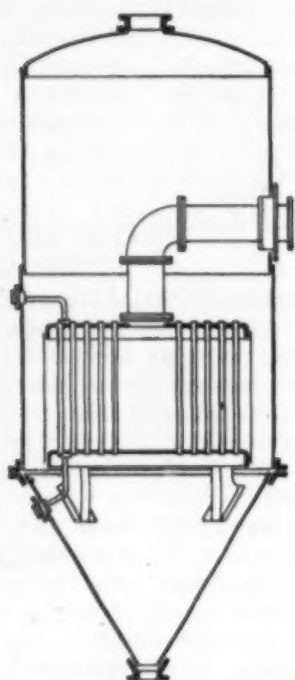


FIG. 2—BASKET TYPE OF VERTICAL TUBE EVAPORATOR

are, then, the results of an effort by the designer to balance the optimum conditions with regard to these factors against excessive complications of construction.

STANDARD VERTICAL TUBE

The majority of evaporators now in operation can be divided into three classes:

- (1) Vertical tube submerged.
- (2) Horizontal tube submerged.
- (3) Film.

The vertical tube is the oldest (dating from about 1850) and is still the favorite abroad. It is sometimes known as the "Standard" or "Robert" evaporator. A common construction is shown in Fig. 1. Two tube sheets *A* and *B* extend across the evaporator, and between them are fastened a number of vertical tubes. Steam is admitted at *C* and fills the space around the tubes and between the tube sheets. Some provision must be made for liquor circulation; in Fig. 1 the central large downtake *D* is provided. This is the usual type, built by all makers.

It is evidently an attempt to emphasize factors *a* and *b*—i.e., circulation velocity and scale removal. The velocity of the liquid is high; and scale, if formed, may be easily drilled out with standard cleaners. But for the best circulation the tubes should be 4 to 6 ft. long, which is unfavorable in its effect on *c*, hydrostatic head. On the steam side steam

velocities are low; condensate must run the whole length of the tube before it can be removed; and because of the lack of definite lines of steam flow in the heating unit, the non-condensable gases are apt to diffuse more or less throughout the steam space.

Many variations of this design exist. To increase the velocity of circulation, several small downtakes may be supplied (Scott, Webre); or the heating unit may be in the form of a removable drum with an annular downtake (Swenson, Zaremba). (See Fig. 2.) This also helps item *b*, as the whole unit may be removed for cleaning, if desired. In all vertical tube evaporators a change in item *d* (tube diameter) affects *a* and *b* in opposite directions; for smaller tubes give more vigorous circulation, but larger tubes are more easily cleaned. The ordinary diameter is 2 to 2½ in.—rarely up to 4 in. Factor *c* can be helped by operating with a low liquor level. This aids heat transfer greatly, but tends to bake on scale or crystalline deposits.

On the steam side, baffles may be put in the vapor space to increase steam velocity and localize the non-condensable gases (Webre). Nothing can be done to improve drainage of condensate.

In general, then, the vertical

evaporator emphasizes the factors affecting heat transfer on the liquor side of the tubes, and is, therefore, to be preferred where the liquor side is more apt to cause trouble. Viscous liquids, liquids tending to form scale or liquids depositing crystals are best handled in a vertical tube evaporator.

HORIZONTAL TUBE EVAPORATORS

The horizontal tube evaporator originated about 1886 in the Bohemian sugar industry as the Wellner-Jelinek, by which name it is still sometimes known. It, like the Standard, is the especial property of no one firm, though each maker has his favorite lines. A typical body is shown in Fig. 3. A bundle of horizontal tubes end in steam chests; into one, steam is introduced; and from the other steam chest the condensate and non-condensable gases are removed.

Here emphasis is placed on the steam side. The steam velocity is positive and high, condensate drains at once to the bottom of the tube, its passage to the end is assisted by the steam velocity, and non-condensable gases are washed to the far steam chest in a positive way. On the liquor side, no especial attention is given to liquor circulation; scale removal is difficult, if not impossible; but there is a relatively small hydro-

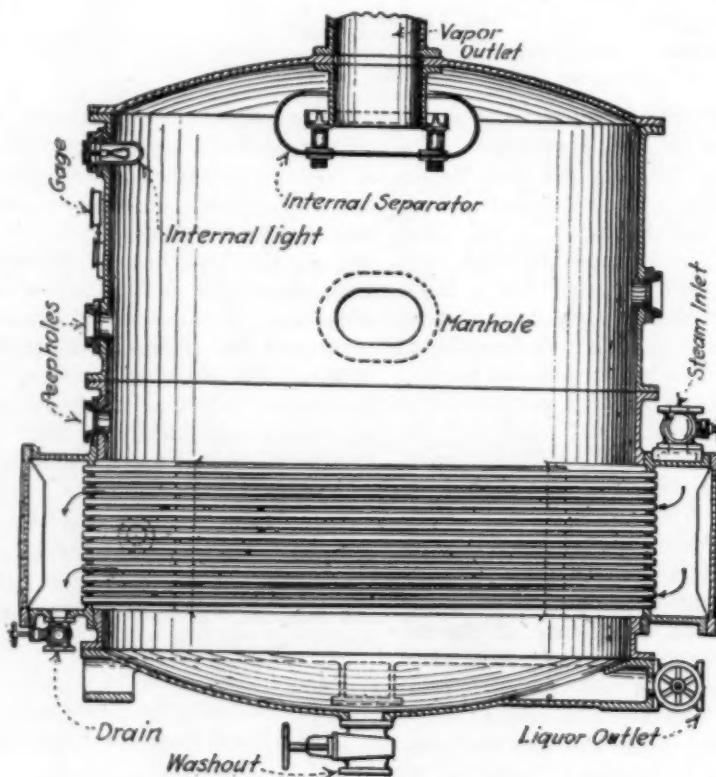


FIG. 3—HORIZONTAL TUBE EVAPORATOR



static head and there is no obstacle to making the tubes as small as desired. Tube diameter cannot be indefinitely decreased, because of cost per square foot and because of labor for changing tubes.

The various makes differ mainly in the shape of the bodies. The body may be square with a pyramidal or half round roof as in the old Wellner-Jelinek design (Swenson) or a vertical cylinder (Zaremba) or a horizontal cylinder (Buffalo). The cylindrical bodies, combined with a tube bank of rectangular outline, are claimed to give better liquor circulation; but they increase floor space, and greatly increase the cost of repairs. On the steam side, all makers use the same arrangement. The

original Wellner-Jelinek had baffles in the steam chest so that steam went through several bundles of tubes in series, but this is not used by any modern designer except in extremely large machines.

The horizontal, then, pays no attention to factors *a* and *b*—though often the circulation in a horizontal may be as vigorous, or more so than in a vertical—and emphasizes factors *c* and *d*, and all the factors on the steam side. No comparative data have ever come to the writer's attention as to the relative rate of heat transfer in the horizontal and in the vertical under strictly comparable conditions. The horizontal is to be preferred, because of simplicity, where there are no difficulties on the liquor side from scale formation, crystal deposits, or viscosity.

FILM TYPES

The film type evaporators are not so easily classified. They are all, however, attempts to emphasize liquor velocity and minimize hydrostatic head. The Kestner (Fig. 4) has a bundle of long narrow tubes in a shell *M*. Steam is admitted at *A*, condensate removed at *E*, and non-condensable gases at *C*. Liquor is fed at *T*, but is allowed to rise only a little way into the tubes. As it begins to boil, the steam bubbles carry liquor along with them; so that the whole tube is wet, but only with a film of liquid. A centrifugal separator *D* removes concentrated liquid, which is drawn off at *L*. The vapors pass through a series of baffles and leave at *B*.

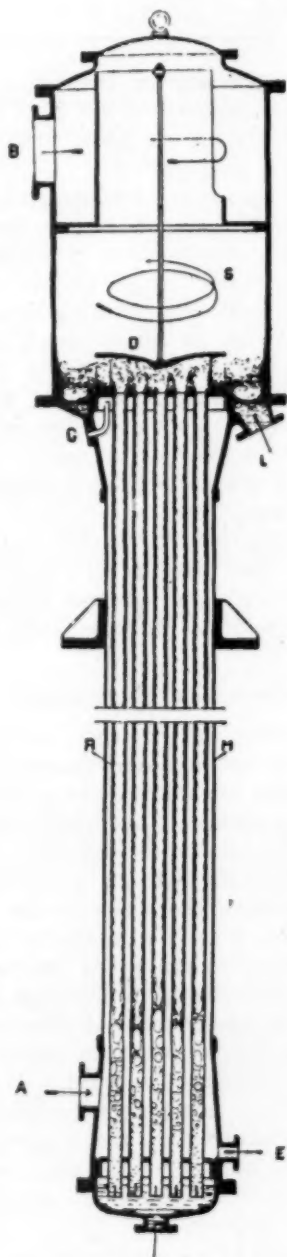


FIG. 4—KESTNER EVAPORATOR

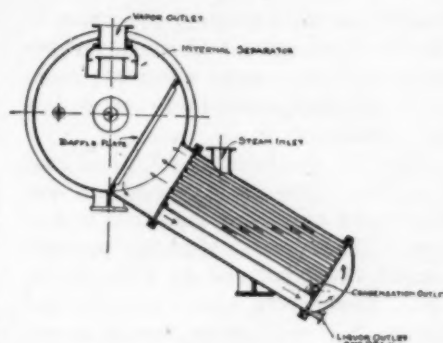


FIG. 5—INCLINED TUBE EVAPORATOR

Here the emphasis is on the liquor side. Liquor velocity is high, hydrostatic head probably low, and tube diameter can be small; but scale removal is difficult (although the makers claim that the high velocities tend to prevent scale formation). On the steam side conditions are about as in the Standard evaporator—drainage worse, but velocity and venting better.

The next step is marked by the inclined evaporator (Fig. 5) of the Buffalo Foundry & Machine Co. This sacrifices some of the velocity of the Kestner and adds somewhat to the hydrostatic heads, thereby gaining in compactness and ease of cleaning, but not improving the steam side conditions much.

YARYAN AND LILLIE

When the tubes become horizontal we have the Yaryan (Fig. 6). The tubes are reduced to a reasonable length, but to obtain the length of travel necessary for film operation, several tubes are united by return bends to form a continuous coil.

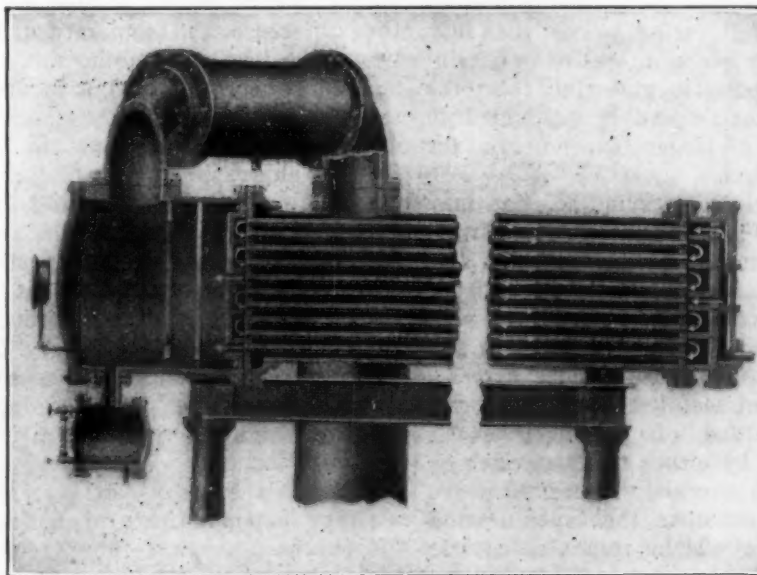


FIG. 6—YARYAN EVAPORATOR



Conditions here are very like those in the Kestner, except that the evaporator is much more compact, more easily cleaned, and more accessible for repairs.

Finally, we have the Lillie (Fig. 7). The tubes are expanded in one tube sheet only, and the other end is free. They are slightly slanted toward the head end to give drainage. There is a small hole in the free end to vent non-condensed gases. Liquor is showered over the tubes by a circulating pump. Here liquor velocity is fairly good, hydrostatic head practically zero, and the steam side conditions are quite good. Steam velocity and condensate drainage are opposed, in contrast to conditions in the regular horizontal. Scale or precipitate removal is difficult; but if

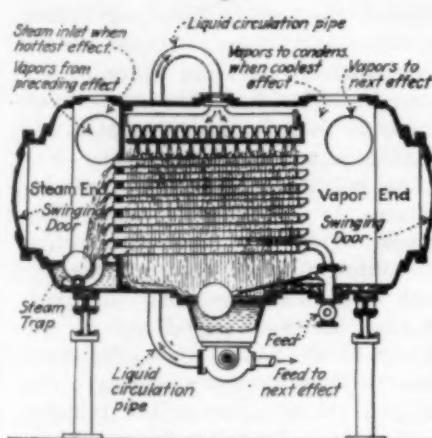


FIG. 7—LILLIE EVAPORATOR

the scale is hard and brittle, it can be cracked off by sudden changes in temperature (usually obtained, if a

multiple effect, by reversals). This construction is complicated and expensive by the time all the circulating pumps and accessories for reversal are included.

There are many other types of evaporators; but few other than those mentioned have a really general application. Special conditions have brought out special constructions, each suitable in its own field, but not generally applicable. The problem of fitting an evaporator to a given process is far more complicated than the discussion above would indicate; and what has been said about the different types is to be considered as only the most general and introductory statement. No one should try to choose an evaporator on the basis of this very elementary outline.

Solving the Evaporation Problems of the Soap Industry

A Practical Discussion of the Recovery of Glycerine From Sweet Water—How Losses Are Prevented and Operation Made More Efficient

BY WALTER E. SANGER

Wurster & Sanger, Chemical Engineers, Chicago, Ill.

THE evaporation problem of the soap industry is to recover glycerine from dilute glycerine solutions which may analyze from 2 to 12 per cent or more of glycerol. The considerable variation in the glycerol content of these solutions is due to the manner in which the glycerol is split off from the triglycerides and is largely under the control of the soap manufacturer. During periods of high glycerine prices the soap manufacturer is interested in obtaining all possible glycerine from the raw materials and is warranted in making a larger expenditure for evaporation.

The dilute glycerine solution may be of two general classes: from sweet water and from spent soap lye. Sweet water is a non-crystallizing solution obtained by the direct splitting off of glycerol from fats or oils and usually contains more glycerol than spent soap lye. The most common method of producing sweet water is by either the Autoclave or Twitchell process. Spent soap lye is obtained upon the saponification of fats or oils by means of caustic (usually caustic soda). The recovery of glycerine from spent soap lyes has already been discussed in the writer's

article in *Chem. & Met.*, vol. 26, No. 26, June 28, 1922.

The oldest type of glycerine evaporator consisted of an open-top tank equipped with closed steam coils. The cost of steam for evaporating with this equipment was approximately the same as for performing this operation in a vacuum evaporator. However, as the rate of evaporation is largely a function of the difference in temperature between the heating medium and the medium being evaporated, it required more equipment to evaporate a given quantity of glycerine solution. A further objection was that, due to lack of circulation in the liquid, salt deposited on the heating coils, thus insulating them and reducing their efficiency. It was also found that the large volumes of steam produced were objectionable in the factory. As the glycerine solution became concentrated, the boiling point rose and required high-pressure steam for concentration.

Early in the history of glycerine recovery soap manufacturers adopted the standard vertical tube type of evaporator operating under vacuum and this is the most common type now in use. Many improvements

have been made in the design of glycerine evaporators, but all of them now operate on the basic principles of vacuum evaporation.

The evaporation of dilute glycerine solutions is confined to the use of single- and double-effect evaporators. The single-effect evaporator is lower in initial cost, but requires approximately twice as much steam as a double-effect doing the same work. For the evaporation of sweet water an evaporator with a shallow dished bottom is employed for rapid circulation. For spent soap lyes the same type of evaporator is equipped with a deep cone bottom so that the salt crystals may have a well-developed form which allows of free filtration of the solution through the salt crystals.

EVAPORATOR ACCESSORIES

Indicating instruments such as recording vacuum and temperature gages have been brought to a high degree of accuracy, and all glycerine evaporators should be equipped with one or the other of these instruments. The recording thermometer has the advantage that the operator may judge the concentration of the liquid. Any sudden change in vacuum may readily be seen on the thermometer chart, as the temperature varies inversely with the vacuum. Water gage columns and peep holes are important features of the evaporator design, as they serve the purpose of indicating the liquid level and the height of boiling.

Catch-alls of various types are provided to aid in the prevention of losses by entrainment as well as boil-

ing over. The most common and least expensive is in the form of a closed cylinder with dished head and bottom. The vapor inlet is at the side and the outlet at the top or vice versa. With either arrangement it is usually supplied with a pipe inside of the catch-all which extends about 15 in. below the bottom of the side vapor pipe. More efficient catch-alls are made in the form of steam separators having fluted walls or with a cylindrical basket (or inner shell) suspended inside of the catch-all, through the walls of which the vapors must pass before leaving the catch-all. There are various types of liners; in one the vapors enter the catch-all tangentially, the entrained liquid is thrown against the curved outer wall of the catch-all by centrifugal force and then runs to the bottom and is returned to the evaporator. The vapors are drawn through the openings in the liner wall and thence pass to the condenser.

SOURCES OF LOSS

Unavoidable, but slight, losses of glycerine are due to entrainment and to the vapor pressure of glycerine solutions. The chief source of loss is through boiling over or spills in the evaporator due to sudden increase of vacuum. Losses by entrainment may be reduced by the proper design of the vapor belt and by the use of a suitable catch-all. Vapor losses in glycerine may be reduced by avoiding the superheating of the liquid and vapors.

The evaporation of spent soap lyes has been discussed by the writer in a former article. At that time there

was taken up the subject of the evaporation of spent soap lyes in a single-effect evaporator.

OPERATING A DOUBLE-EFFECT

A double-effect evaporator unit for the evaporation of sweet water consists of two evaporators, catch-all, condenser, vacuum pump and condensation pump. In starting such an evaporator, the valves are so set that steam will enter the calandria of the first effect and the vapors from the first effect will pass into the calandria of the second effect. The condensation drain from the first effect is connected to a steam trap; the condensation drain from the second effect is connected to both a service pump and to a steam trap. The calandria of the second effect is vented near the top into the vapor belt of the second effect to take care of non-condensable vapors which accumulate in this part of the calandria. The vapor line from the second effect is connected to the catch-all thence to the condenser and vacuum pump.

When starting operation with the double-effect evaporator, vacuum is pulled on both of the evaporators until they are under a vacuum of 15 in. Fresh liquid is drawn into both evaporators to a height about one-third of the height of the calandria. When the vacuum reaches about 23 in., steam is slowly turned into the calandria of the first effect. When the liquid in the first effect begins to boil, the vacuum on the first effect will drop. The vapors pass from the vapor belt of the first effect into the calandria of the second

effect, where they are condensed and are withdrawn through the service pump. As the vapors are condensed the vacuum again rises, but the starting of the evaporators should be done sufficiently slowly that there will be the minimum drop and subsequent rise in vacuum.

When the liquid boils in the first effect, more steam is turned on until there is just a positive pressure on the condensation drain. Under these conditions the evaporator unit is operating at normal capacity and there will be a difference in vacuum between the two effects of about 10 in. When the liquid in the second effect begins to boil, more liquid is fed from the first effect into the second effect and also from the feed tank to the first effect so as to maintain practically constant levels. As concentration increases in the second effect, it also increases in the first effect and the vacuum difference between the two effects becomes greater. When the stage of "half-crude" glycerine is reached in the second effect the rate of evaporation decreases markedly. The pressure on the calandria of the first effect increases and the vacuum on the first effect decreases; the vacuum on the second effect increases. When the liquid reaches the "half-crude" stage

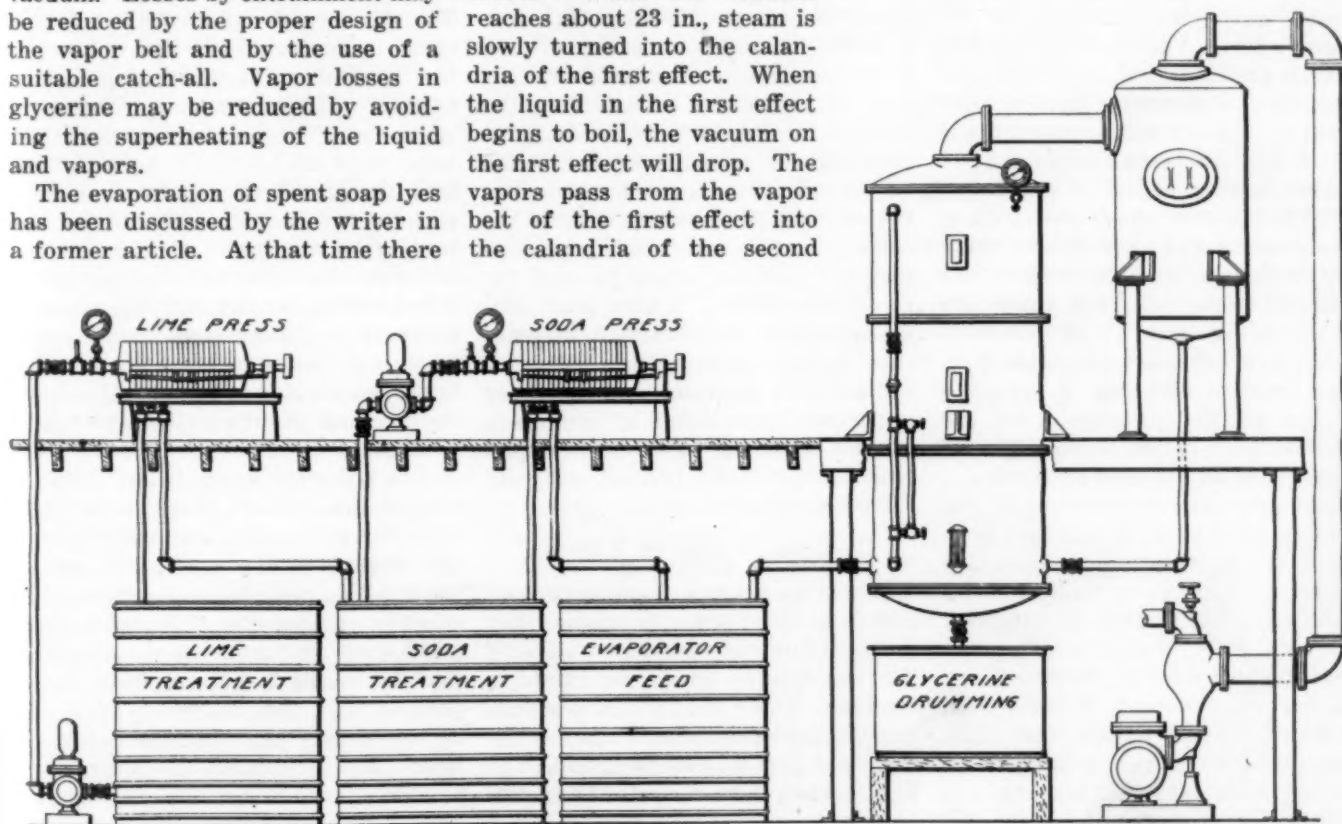
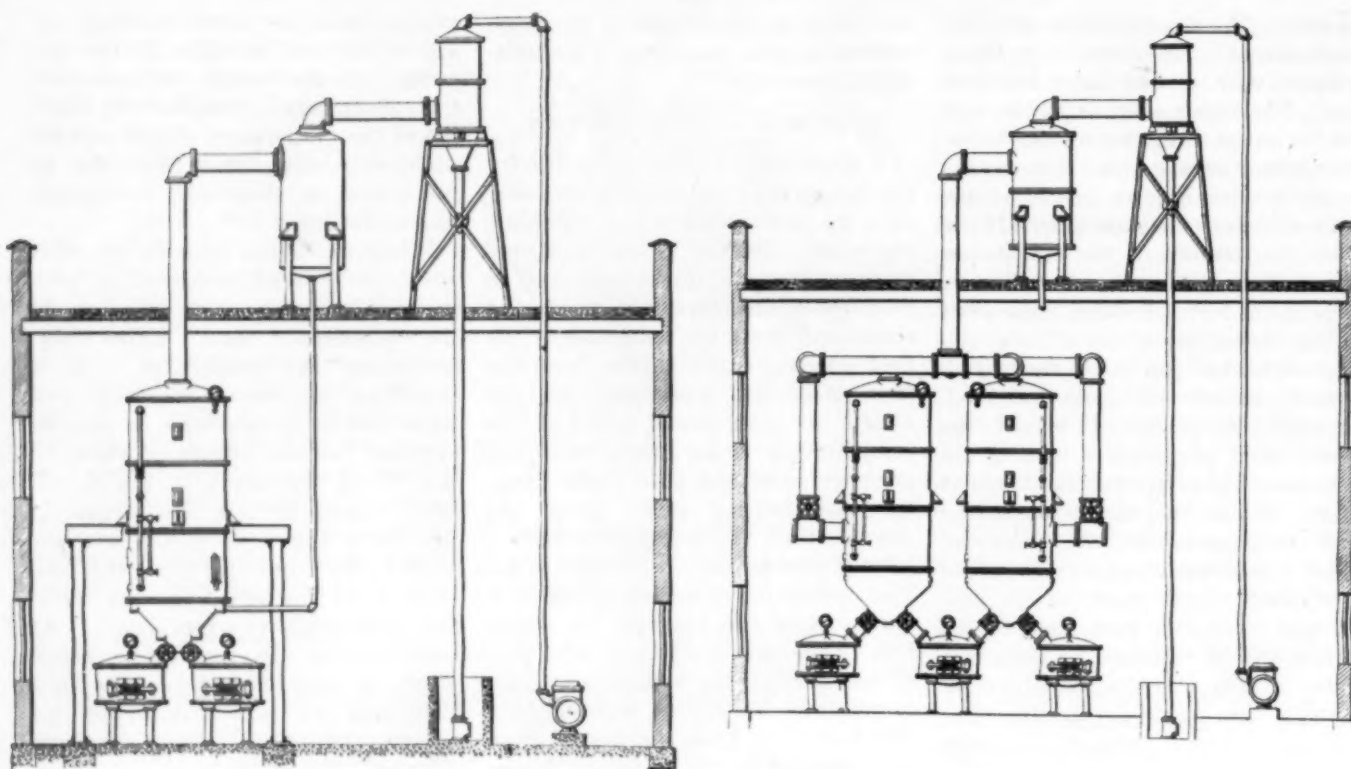


FIG. 1—A SAPONIFICATION CRUDE GLYCERINE PLANT



FIGS. 2 AND 3—SINGLE- AND DOUBLE-EFFECT CRYSTALLIZING UNITS

of concentration, steam is shut off from the calandria of the first effect; the vapor line from the first effect is shut off and the condensation drain from the second effect is connected to the trap. Live steam is then turned on to the calandria of the second effect. The liquid in the first effect is gradually fed into the second effect and any partly concentrated liquid from a previous evaporation is drawn into the second effect. After a short further period of concentration, the pressure on the calandria of the second effect (which is now being run as a single-effect evaporator) rises and is maintained at a pressure not exceeding 15 lb. When the temperature of the concentrated glycerine reaches 170 deg. F. under a vacuum of 27.5 in. or more, the saponification crude should analyze in excess of 88 per cent glycerol.

Regularly, the temperature of the liquid in a glycerine evaporator is in excess of the temperature necessary to induce boiling as indicated by ebullition. The degree of superheat increases quite regularly after the concentration of the glycerine has reached 50 per cent glycerol. In tests which the writer has made under normal operating conditions, this degree of superheat amounted to 10 deg. F. in the case of 50 per cent glycerol solution and to 32 deg. F.

in 80 per cent glycerol solution. These figures were influenced by the fact that the solution came in contact with the thermometer bulb. Making the same observations on the vapor line between the catch-all and the condenser, it was found that the superheat exceeded 30 deg. F.

When the concentration of the glycerine solution exceeds 50 per cent, it is possible to superheat the solution very quickly by suddenly increasing the pressure of the steam on the calandria. In order to induce evaporation it is necessary that the calandria tubes be at a higher temperature than the boiling point of the glycerine solution. Under these conditions, the liquid itself becomes superheated, some vapors come in contact with the tubes and the vapor is further superheated by coming in contact with the particles of liquid which, as already pointed out, are themselves superheated.

DISASTROUS RISE IN VACUUM

While the sources of glycerine loss just mentioned are appreciable, they are a minor item as compared with the losses due to sudden rise in vacuum. There are two periods during the process of evaporation when this condition is likely to obtain. The first is when the evaporator is started in operation and the second when the water supply to the condenser

suddenly stops and then suddenly starts.

When starting an evaporator in operation, the vapors generated in the evaporator tend to reduce the vacuum to a degree depending on the rate at which they are generated. The vacuum will fall until the vapors come in contact with the water in the condenser, at which time the vacuum will rise suddenly. Turning steam into the calandria when the vacuum is 25 in., it is possible to heat the liquid so rapidly that the vacuum will be reduced to 15 in. or less before the vapors come into contact with the water in the condenser. When the vapors mix with the water, there is a sudden rise in vacuum which may cause the complete charge in the evaporator to be pulled beyond the catch-all into the condenser where it is lost.

Any glycerine which is lost during evaporation must pass from the evaporator through the vapor pipe and thence to the condenser, when the condensation drain is not inside of the evaporator. Evaporating spent soap lye, the condensing water may be tested for NaCl. The usual procedure in this matter is to have a bleeder on the condenser water line, thus obtaining a continuous sample of the water for the entire period of evaporation. This proves satisfactory where an evaporator is



improperly designed and so has a continuous entrainment loss. However, there is usually required in excess of 20 lb. of water per lb. of steam condensed, and where the loss is occasioned by infrequent boiling over of the evaporator, this method of determining glycerine losses is unsatisfactory.

DETECTING LOSSES WITH THE TELLTALE

A more satisfactory method of detecting loss is by the use of telltales. A telltale is a small pipe which is inserted inside of the vapor line, being in the form of a half circle for that portion which is inside of the vapor pipe, the remainder being of full pipe size and screwed into the bottom of the vapor pipe. The half circle should project below the lower edge of the vapor pipe so as to catch any condensed liquid in the bottom of the vapor pipe. It should be so placed that the concave surface faces the direction from which the vapors are flowing. The lower end of the telltale should be equipped with a valve at a convenient distance from the floor; between this valve and the floor there should be a water-gage column for collecting the sample, which should be removed at frequent intervals. If the lower part of the half circle is above the bottom of the vapor pipe, probably no samples will be obtained, as the vapors impinging against the baffle will be broken up and carried along with the vapors, which travel at a considerably higher velocity than the vapors in the body of the evaporator. The vapor pipe acts as an air-cooled condenser and will first condense those vapors highest in glycerine. The results of analyses of telltales are therefore relative and not absolute. The vapors condensed in the vapor pipe will collect on the bottom and be carried along in the direction of the flow of vapors. If the lower end of the half circle is below the bottom of the inside of the vapor pipe, telltales will be obtained.

In the evaporation of sweet water these telltales may be analyzed for glycerine; in the evaporation of spent soap lyes they may be analyzed for both glycerine and salt. In the case of soap lye evaporation, the relation between the salt and glycerine contents of the telltales is an indication of the source of glycerine loss. The following table will show the results of a cycle of the production of crude glycerine from spent soap lyes, the

telltale having been placed between the catch-all and the condenser.

Time	Temp. Deg. F.	Per Cent of NaCl	Per Cent of Glycerol
11:45 A.M.	157.5	0.35	6.52
12:00	147.5	0.06	0.50
12:15 P.M.	151.0	0.06	0.30
12:30	152.0	0.06	0.25
12:45	153.0	0.06	0.25
1:00	154.0	0.06	0.25
1:15	155.0	0.06	0.20
1:30	156.8	0.06	0.25
1:45	158.0	0.06	0.25
2:00	161.8	0.06	0.35
2:15	166.5	0.06	0.40
2:30	167.0	0.06	0.30
2:45	167.8	0.03	0.35
3:00	167.8	0.03	0.50
3:15	173.1	0.06	0.90
3:30	174.4	0.06	1.15
3:45	174.4	0.06	1.00
4:00	178.2	0.06	1.25
4:15	185.4	0.06	1.79
4:30	198.5	0.06	1.89
4:45	200.0	0.06	2.49

In this table it will be noted that the first telltale analyzed high in both salt and glycerol. This is accounted for by the fact that steam was turned on the evaporator when the vacuum was 25.4 in.; before the vapors reached the condenser the vacuum had dropped to 22.3 in. and then suddenly rose to 25.0 in., thus pulling over some of the spent lye from the evaporator into the condenser, where it was lost. A vacuum of approximately 25 in. was maintained throughout the main part of the run, the finish being made under a vacuum of 27.6 in. and a temperature of 200 deg. F.

It is to be particularly noted that after the temperature reached 170 deg. F. the salt content remained constant, while the glycerol content increased from 0.50 to 2.49 per cent. This shows the tendency of glycerol to distill over with the evaporator vapors at a temperature in excess of 170 deg. F. Crude glycerine should be finished under temperature conditions as low as possible.

CIRCULATING A MINIMUM OF WATER

The safest course to pursue in the evaporation of glycerine liquids is to circulate the condensing water, which should be analyzed at frequent intervals. In order that this precaution may be of value, there should be in circulation only the minimum amount of water that will answer the purpose. This is due to the fact that if a large volume of water is in circulation, the dilution of the glycerine lost from the evaporator will be so great that the cost of glycerine recovery would exceed the value of the glycerine. Where the cost of fresh water is sufficiently high, it is economical to use circulating water.

The amount of condensing water required for evaporation increases very rapidly with increase of

vacuum. The temperature of condensing water decreases as the vacuum increases. For purposes of illustration, we can assume that in the evaporation of water the temperature of the water after condensation is 5 deg. F. lower than the temperature of steam corresponding to the vacuum; that the barometer is 29.92 in., and that evaporation is carried on under a vacuum of 23.41 in., 26.08 in. and 28.0 in.; the temperatures for these vacuums are taken from Marks & Davis' Steam Tables.

The temperature of steam at 23.41 in. of vacuum is 144 deg. F. The temperature of the water after condensation will be 139 deg. F. The temperature of steam at 26.08 in. of vacuum is 124 deg. F. and the temperature of the water after condensation will be 119 deg. F. The temperature of steam at 28.0 in. of vacuum is 100 deg. F. and the temperature of the water condensation will be 95 deg. F. Assume further that the temperature of the water entering the condenser is 70 deg. F.

CALCULATING QUANTITY OF CONDENSING WATER

Kent gives the following formula for determining the quantity of condensing water required in evaporation under vacuum:

$$Q = \frac{1114 + 0.3T_1 - T_2}{T_2 - T_0}$$

wherein

T_1 is the temperature of steam at the exhaust pressure;

T_2 is the temperature of the cooling water entering the condenser;

T_0 is the temperature of the water after condensation;

Q is the number of pounds of cooling water required per pound steam condensed.

Evaporating under 23.41 in. of vacuum, as above outlined,

$$Q = \frac{1114 + 0.3(144) - 139}{139 - 70}$$

= 14.8 lb. of water per lb. of steam condensed.

Evaporating under 26.08 in. of vacuum, as above outlined,

$$Q = \frac{1114 + 0.3(124) - 119}{119 - 70}$$

= 21.0 lb. of water per lb. of steam condensed.

Evaporating under 28.0 in. of vacuum, as above outlined,

$$Q = \frac{1114 + 0.3(100) - 95}{95 - 70}$$

= 42.0 lb. of water per lb. of steam condensed.



Distillation

MANY unit processes have been handed to the production men in the chemical engineering industries fully developed, or fully enough developed to be available for use. Distillation is not an exception in many ways, for as a process it is as old as distilled liquors. But the most significant developments in the field of distillation have been carried out for our own industries by chemical engineers and other production men. Nor has the impetus of creative development showed any signs of letting up. The past year has developed new tower packings, new plate designs, new fractionating columns and has contributed extensively to the theory of fractionation. Recently a new petroleum still was reported

to us that indicated a marked advance in both design and productive capacity.

Our treatment of this subject has followed two lines. First, we have an article by E. J. Winter on the general subject of fractional distillation, discussing the various types of problems that are met in the chemical engineering industries, types of equipment and their relative efficiency and some of the difficulties of controlling the process.

The second article is on one of *Chem. & Met.*'s favorite themes—eliminating waste. Dr. Arnstein discusses the value of distillation in the recovery of wastes and the economic utility of the products so recovered, in particular the production of motor alcohol from molasses.

Fractional Distillation

Operating Practice in Fractionating Simple or Complex Mixtures in Intermittent or Continuous Stills, With a Discussion of an Old Savalle Rectangular Column Which Has Never Been Surpassed

BY E. J. WINTER

Consulting Engineer, New York City

DISTILLATION is a special form of evaporation, for the purpose of separating liquids from other liquids or from solids. Fractional distillation is the method usually employed for the purification and separation of the volatile constituents of a mixture.

The theory of fractional distillation is a very interesting but unfinished chapter of modern physical chemistry. There is a revival of interest in this subject, and a good deal of useful material has been published recently. Unfortunately, the theory covers the simplest cases only; the rules for more involved cases of fractional distillation are still largely empirical.

FRACTIONATION OF SIMPLE MIXTURES

The simplest case is where the constituents are completely miscible in one another in all proportions, and no chemical affinity exists among them. A mixture of such liquids may be separated into its constituents by fractional distillation, because of the difference in volatilities of said constituents. Mixtures containing various members of the same series, and nothing else, belong to this case, and they present the simplest problems of fractional distillation. A rough but quite satisfactory separation of the

paraffin series is obtained by the oil distiller through fractional condensation—the least effective method of fractionation. Separation of benzene and toluene, a very popular example in text books, requires little as to equipment and still less as to skill.

There are eight isomerides of amyl alcohol, of the general formula of $C_5H_{11}OH$. Several of their boiling points are close together, yet the separation of a mixture of these isomerides presents no particular difficulties, and the progress of "rectification" may be predicted with a reasonable accuracy, if the composition of the mixture is known.

CASES WHERE SEPARATION IS MORE DIFFICULT

The problem becomes more difficult when there exists an affinity between two or more of the constituents, or whenever they are not completely soluble in one another. There may be present a number of compounds, not uniformly soluble in one another and very different as to volatility. In all such cases, whether the substances are soluble in one another or not, or partly soluble, or even wholly immiscible, they exert some influence on one another, and may cause considerable difficulties in frac-

tional distillation. A particular constituent may behave quite differently at the base of the column than near the top. It may be present in minute quantities only, it may be a mere impurity in the feed, nevertheless it may accumulate and stay on certain plates and have no tendency to leave either with the distillate or with the residue.

The presence of ethanol, up to approximately 50 per cent by volume, has only a negligible influence on the vapor pressure of the water, and the proportions of water in the distillate will be the same as if the two were immiscible. The vapor pressure of alcohol, however, is reduced considerably. Judging merely by its action upon the vapor pressure of the water, ethanol is not as miscible with water as methanol, and a fractional distillation of the three shows it.

The purification of the distiller's high-wines is complicated by the "impurities," some of them more miscible in ethanol than water (higher alcohols, ethers, etc.), others more miscible with water (ammonia); moreover, the plates of the distilling column are seats of endless chemical reactions, the products are mostly more volatile than the alcohol, and, forming from less volatile compounds, pass constantly through the purified alcohol.

EQUIPMENT FOR FRACTIONAL DISTILLATION

Distillation may be carried out intermittently or continuously. An intermittent or charge still consists of kettle, fractionating column, dephlegmator (separator) and con-



denser (cooler). A continuous still consists of the same elements, except that the kettle is omitted and the heat is applied direct to the column. The usual method of heating is by means of steam, either direct or indirect.

DESIGNING STEAM COILS FOR KETTLES

The kettle is usually 50 per cent larger than the volume of the charge, so that this latter will occupy only two-thirds of the kettle volume. This leaves room for expansion and foaming. Vertical cylindrical kettles leave more room for foaming than horizontal cylindrical kettles, but, as a rule, foaming in kettles is easily taken care of, and horizontal cylindrical kettles are easier to locate without leaving dead spaces, and the heating coils are simpler, requiring less bending. Except for small kettles, the steam coil must not be of a single length of tube, but the incoming steam should be split up and passed through branches not exceeding 200 diameters. These coils contain condensing steam, and they are submerged in a boiling solution. The heat transmitted per square foot per degree per hour is a definite figure; assuming a temperature difference of 30 or 40 deg. C., 200 diameters will condense all the steam the tube may carry at 4 or 5 lb. gage pressure and

at a velocity of 6,000 ft. per minute. Higher velocities increase the rate of heat transmission per degree, but this is far overbalanced by the drop of pressure and temperature, due to high velocities, and the consequent decrease in the difference of temperatures between steam and boiling liquid.

Direct steam is introduced through a perforated pipe, called a "sparger." The area of the perforations should not exceed the cross-sectional area of the tube, otherwise the pressure at the tail end of the sparger may decrease to a point where the solution in the kettle will pass into the sparger. The sparger pipe may be bent into a circle or coil, and if the above rule is not observed, there may be suction within the tube, solution drawn in at certain points and discharged at others. Solids in the solution may cause regular sand-blasting, which is to be avoided under all circumstances. Even under favorable conditions, spargers wear out quickly, unless heavy metal is used.

These details are mentioned to show that great care and considerable experience is required in the design of distilling equipment.

Previously the kettle was of such dimensions as to enable the still runner to finish a charge in either 12 or 24 hours. This included charging,

heating to boil, fractionating and discharging of the residue. Recently much larger kettles are used, a 72-hour period being quite usual. The advantages of large charges are: saving of time and labor, better fractionating, especially where the distillate consists of a large number of constituents and a clean separation is desired. There are fewer stops and cooling down of the apparatus, thus saving subsequent reheating, but the charge must be kept at boiling temperatures longer, and the radiation losses increase; altogether, there is no appreciable change in the steam consumption.

PLATE VS. FILLER TOWERS

The "true" column consists of an upright cylindrical shell and a number of horizontal plates built into the shell. The plates are provided with overflow pipes, to carry the refluxes of the dephlegmator to the base of the column and to the kettle, if used. The steam or vapor passages of the plates may be simple perforations, or the more efficient vapor pipes and caps.

A "filler" column consists usually of an upright cylindrical shell, filled with metal rings, hollow balls, stoneware, porcelain or even stone or coke cylinders, prisms or other shapes offering a large wetted surface. Occasionally a bundle of small tubes is used, each tube containing a chain, nearly filling the tube.

The efficiency of these fillers is away below that of the true columns. Uniform distribution of the trickling liquor over all surfaces is a problem that will probably remain unsolved, thus introducing an element of chance. The reduction of the cross-sectional area of the column is not uniform, and the many uncertainties make a reliable calculation of capacities impossible. Moreover, they are not stable, but, in a very delicate equilibrium, easily disarranged.

WHY THE PLATES ARE SO EFFICIENT

The true column is very efficient and stable: the vapors entering from the kettle at the base of the column containing, say, 15 per cent of ethyl alcohol and 85 per cent of water pass to the top of the column in a few seconds, yet arrive there at a high concentration, 96 per cent or over. This condition is stable; no small disarrangement of heat supply, reflux, etc., will disturb it; such disarrangements must go a long way before affecting noticeably the working of

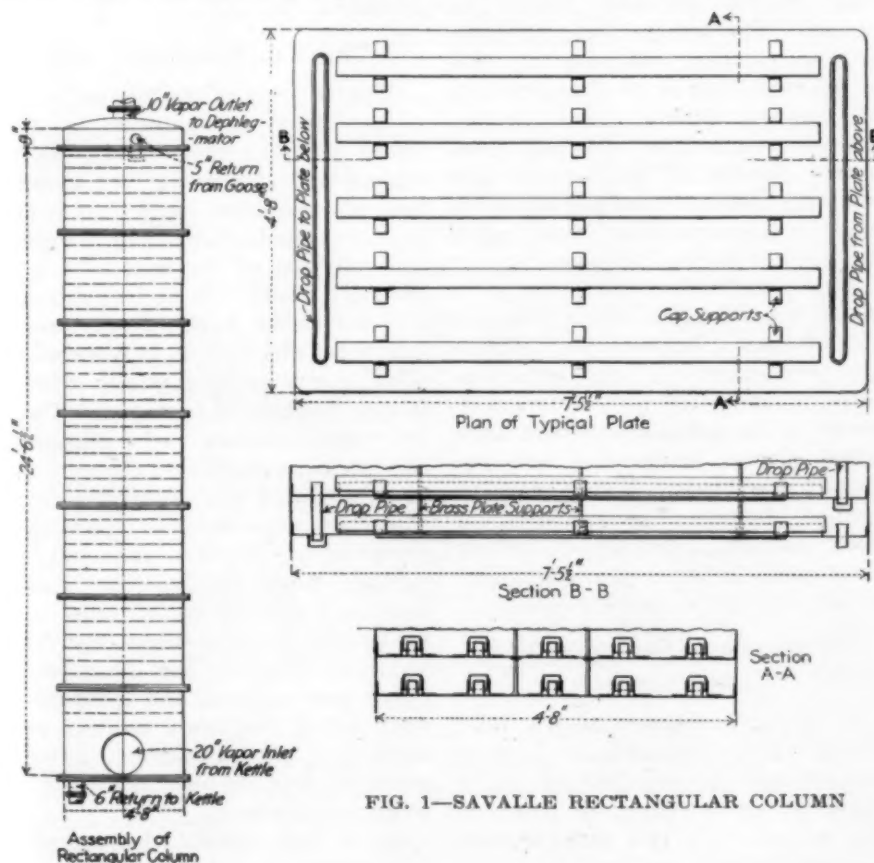


FIG. 1—SAVALLE RECTANGULAR COLUMN

the column. The high efficiency of the plates is due to two causes:

1. The vapors pass into the liquid seal of the plates in small bubbles, exposing large surfaces. The bubbles pass in a horizontal direction before rising to the surface. These vapors, although saturated, originate from the plate below, are not in equilibrium with the liquor phase, which is cooler, and may be cooler by a couple of degrees than the vapors themselves. There is a partial condensation and a corresponding evaporation of the liquid, due to the latent heat set free. The washing and the contact are nearly perfect, the exchange of constituents and establishment of equilibrium between phases nearly complete. The plates, however, must be so constructed that these requirements be fulfilled; hence the use of slotted, perforated or saw-toothed caps (according to Barbet-Mariller).

2. The wetted surface, which is an expression of efficiency, is very large, because, in a true column, the vapors come into contact with the finely pulverized, exploded bubbles, which explode into thousands of pieces, whirl and are thrown in every direction. The vapors pass through a misty liquid phase; such contact of the two phases is impossible in a filler column (according to Hausbrand).

It is interesting to note that although both causes are undoubtedly operative in a true column, the fundamental conception of these causes is still affecting the apparatus builders; the French column-caps are provided with slots, perforations and saw-teeth, while German builders are very seldom using them. They both agree on having a long vapor line—i.e., narrow vapor tubes and small caps.

AN OLD RECTANGULAR CONSTRUCTION WHICH REMAINS UNSURPASSED

Fig. 1 shows details of an old Savalle column. Text books show these columns diagrammatically, as of historical interest only. The U. S. Food Products Corporation has several of these columns in its Louisville, Ky., and Peoria, Ill., plants, those in Peoria having been installed 35 years ago, and even then they were not new. These columns were never surpassed as to efficiency of fractionation, ease of operation or entire freedom of structural troubles.

We have obtained on these columns, consistently, alcohol from black strap molasses fermentation,

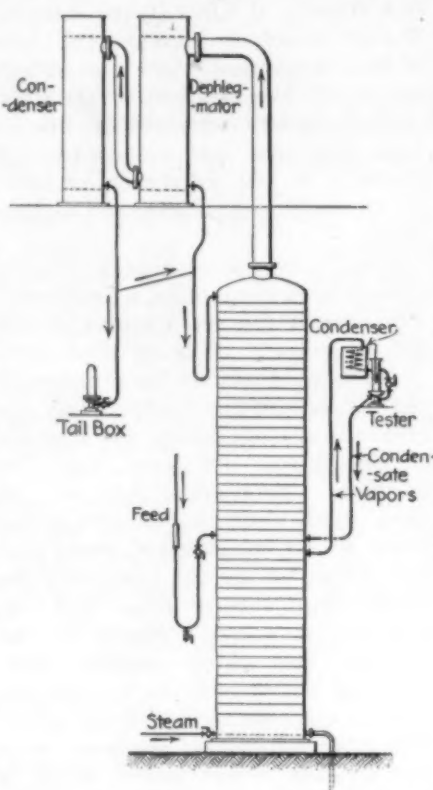


FIG. 2—CONTROL FOR CONTINUOUS DISTILLATION

which gave a "middle-middle run" of 25 per cent that held the customary permanganate test during 75 minutes. These columns were described by old distillery experts as equal to any, although they had at least twelve different makes to handle. The spirits, even 2 years after distillation, were entirely free of odors ordinarily so characteristic of molasses alcohol. Such results, however, cannot be obtained from poorly fermented mashes on any column. The quality of the alcohol is made in the fermenting room; but it may be lost in the still room.

This illustration will show at a glance why the Savalle columns are out of date. Rectangular columns are very expensive, good workmanship is required for satisfactory work; it is largely a question of hand labor, plenty, inexpensive and unusually high grade. They may be studied, however, as examples of good column construction, which stood up under the most exacting conditions during two generations.

CONTROL OF CONTINUOUS DISTILLATION

It is not convenient to use filler columns for continuous distillation, because the feed can not be introduced at an intermediate point on the column, and two superimposed columns have to be used.

Fig. 2 shows the proper method of control for continuous distillation. We hope it will be more generally adopted. Columns are built with considerably more plates than the "theoretical," and in case the composition of the feed changes, it may happen that more of the more volatile constituent is discharged than is fed into the column. The effect will not be noticeable immediately at the tail-box, or tester, but the column becomes depleted of the more volatile constituent, and when the effect becomes noticeable at the tail-box, it will require much time to readjust the feed and discharge. Therefore a vapor sample is to be taken occasionally at an intermediate point, as shown, where the column is the most sensitive, and where such a deficiency in feed becomes noticeable immediately. Suppose it is a solvent recovery column and the feed becomes poorer in solvent—i.e., it becomes more dilute. In this case the test will show a decrease in proof long before it becomes apparent at the tail-box.

The same figure shows Barbet's constant-flow principle. The distillate from the condenser must pass through a valve, which maintains the flow constant, the excess returning to the column. This arrangement rectifies automatically the effects of small changes in the supply of heat or cooling water.

THERMAL EFFICIENCY LOW

The efficiency of the process is low, if the steam consumption is compared with the theoretical work of separation (change in free energy, heat of dissolution, etc.). This is due mostly to the inefficiency of the cycle, the rejection of the heat at a temperature where it is no longer available for useful work. Nevertheless, fractional distillation, in one case at least, competes successfully with a largely mechanical operation. There are two classes of ammonia-refrigerating machines: the compression type and the absorption type. The first type involves mechanical compression of the gas and no further heat supply; the second requires absorption of the ammonia in water and subsequent fractional distillation, the compression being now omitted, and inexpensive pumping of the liquid solution substituted. The absorption process seems to hold its own, especially on large installations.

Or is this merely the exception that proves the rule?



Recovering Values From Waste Products by Distillation

The Manufacture of Yeast, Alcohol, Ether and Other Products From the Waste of Sugar Plantations and Farms Forms the Basis of a Profitable Industry and Makes Substitute for Gasoline

By DR. HENRY ARNSTEIN
Consulting Engineer, Philadelphia, Pa.

FOR the layman prohibition may have seemed to mean the end of the alcohol industry. As a matter of fact, we are just commencing to produce and use alcohol. The readers of this paper will be acquainted with the important rôle of alcohol in the chemical, pharmaceutical, textile and dye industries; but the use of alcohol as motor fuel will consume in the near future such large quantities as to stagger the imagination of even those who are acquainted with this branch of science and industry.

During the recent war we were told to preserve sugar and by clever manipulation on the part of European brokers almost the entire sugar world was led to believe that a great sugar shortage existed and the price skyrocketed. When the awakening came, most of the sugar producers, in Cuba and elsewhere, found themselves in the hands of

receivers and very severe losses were suffered by practically all the large refineries in this country.

Necessity being the mother of invention, the sugar industry naturally sought a new outlet for its products. Approximately 25 per cent of the sugar produced is in the form of molasses. Until recently this product had very little value, although here and there a distillery produced rum and other beverages from it. The greatest part of this molasses was dumped in the ocean or otherwise wasted.

In sugar-growing countries such as Cuba and Natal, where oil is not found and gasoline is consequently expensive, it was long ago discovered that alcohol could take the place of petroleum distillates. Alcohol has been used in some parts of Europe as a fuel for internal combustion engines for the past 25 years with great success. It has been found

that alcohol so used possesses undoubted advantages. According to Mustil, petroleum spirit gives 15 to 18 per cent efficiency; petroleum, 13 per cent; steam, 13 per cent; gas, 18 to 31 per cent and alcohol, 23 to 25 per cent. This shows alcohol as more efficient than any other liquid fuel. Also, the piston rings and valves of an alcohol-using engine wear much longer than when other fuels are used.

ALCOHOL PRODUCED FROM YEAST MANUFACTURE

Alcohol is obtained as a byproduct of the manufacture of bakers' yeast. One gallon of molasses yields 4 to 4½ lb. of compressed yeast and 0.6 gal. of proof spirit. With very dilute mashes the yeast will consume alcohol as if it were sugar and the yield is raised to 6 or 7 lb. By excessive aëration it is possible to produce a pound of yeast for each pound of molasses used. For this reason most yeast is now made from molasses rather than from grain.

The yeast industry will probably increase greatly in this country. We have fewer than twenty yeast factories today, while in Germany, prior to 1914, there were 502 yeast factories in operation and ten more, each of a daily capacity of 418,000 lb. of compressed yeast, were built

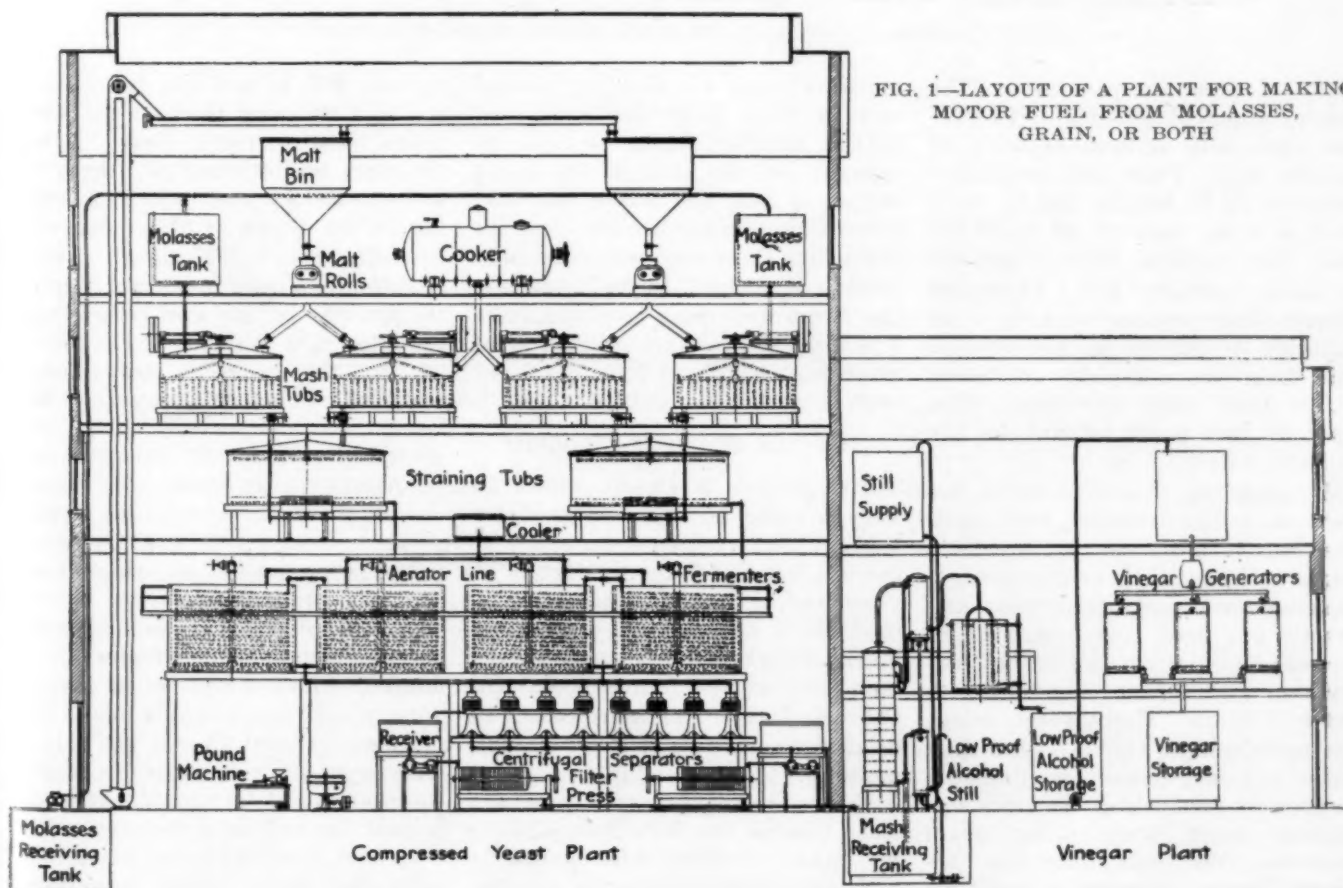


FIG. 1—LAYOUT OF A PLANT FOR MAKING MOTOR FUEL FROM MOLASSES, GRAIN, OR BOTH



during the war. This yeast was mainly used as fodder to replace the 5,000,000 tons of cattle foods imported annually prior to the war.

As an illustration of this development, it is only necessary to cite the plant of the Dessauer Zuckerraffinerie, G.m.b.H., in Dessau-Anhalt. This factory consumes 175,000 kg. of raw material daily. It produces 190,000 kg. of compressed yeast daily, equal to 56,000 kg. of dried fodder yeast. The power plant has six turbo-compressors of 24,000 hp. actual capacity, delivering 4,237,200

was that the yeast maker used less corn and more rye, realizing that a vigorous yeast needs more nitrogenous matter than an alcohol mash.

When yeast making became more important, the mash was filtered when grain mash was used, and the clear filtrate was fermented with thorough aëration during the process. Depending on the process, fermentation lasts 8 to 16 hours. The yeast is then allowed to ripen for an hour or so. Then it is separated from the mash in centrifugals.

The main difference between the

Directly under the malt bins are two mills for disintegrating the malt (which is used for converting the starch into sugar).

From the mash tubs the mash flows by gravity to the filter tanks, which are large steel vessels having perforated or slotted false, bronze bottoms and from eight to thirty-two outlets. These outlets are connected with air and hot water supplies to permit thorough agitation and extraction of sugar.

In the beginning of the operation the wort, as the filtered mash is

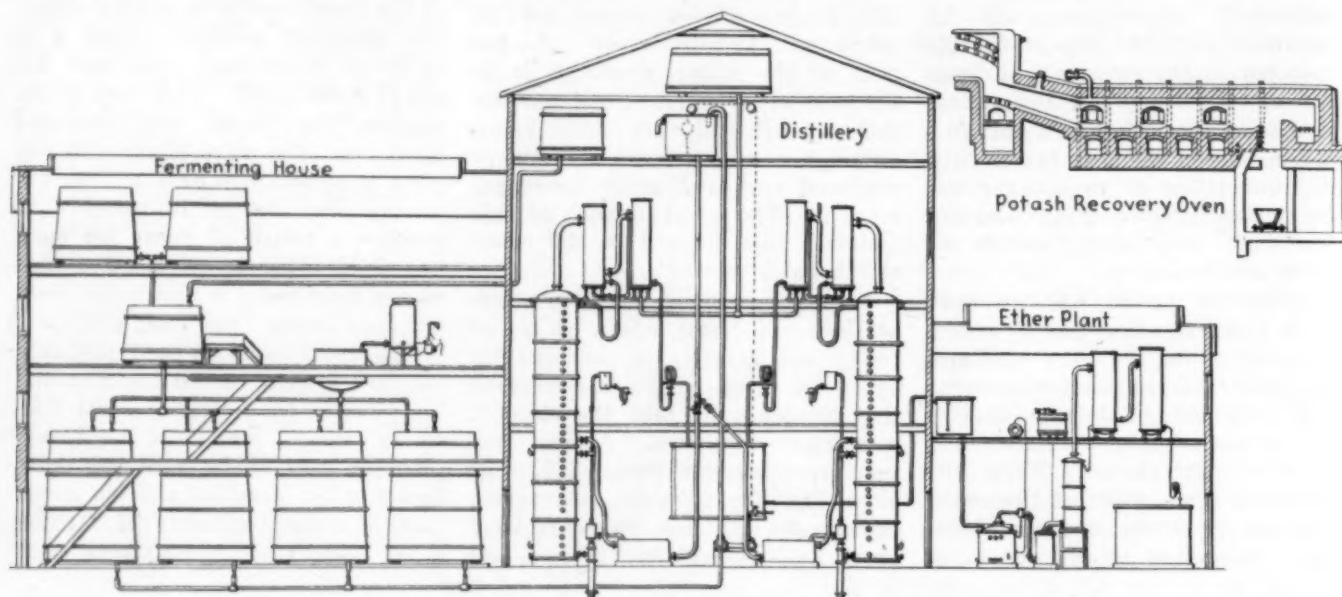


FIG. 2—A MOTOR ALCOHOL PLANT WITH ETHER PLANT INCLUDED

cu.ft. of free air per hour. The mash equipment consists of twenty-one tubs with a total capacity of 118,890 gal. There are seven fermentors, 92 ft. long by 29½ ft. wide, with a total capacity of 1,109,643 gal. The settlers have a capacity of about 1,000,000 gal. There are thirty filter presses with a total capacity of 99,000 lb. per charge. The drier has a capacity of 20,000 lb. of dried yeast per hour. Pipe lines in this plant amount to 12½ miles in length.

If grain or starch products are used to produce alcohol and yeast, the starch must be converted to sugar by using acids or enzymes. If molasses or other saccharinous materials are used, the sugar is inverted by slightly acidifying and boiling with steam, eliminating a costly process. Early yeast manufacturers wanted alcohol rather than yeast and so followed the distiller's method of fermenting the thick unfiltered mash when using grain mashes. The only difference between the two processes at that time

apparatus used for distilling alcohol from a yeast mash and that used with a distillery mash is that the capacity of the still in the yeast factory is less, due to the fact that more diluted materials are used for yeast than those used when the main product is alcohol. In the latter case the fermented mash contains from 7 to 9 per cent alcohol, while a yeast mash has only from 0.75 to 1.6 per cent.

HOW THE PLANT IS DESIGNED

The process is clearly shown in Fig. 1. The plant is designed for using either molasses or grain or the two mixed, for the production of yeast and alcohol. In case grain is used alone, the elevator at the left of the figure lifts the malt to the malt bins on the fourth floor. On the same floor is a pressure cooker to gelatinize corn, rice or other starchy material. The gelatinized material is blown under pressure into the mash tubs on the third floor. These are tanks supplied with agitators and temperature-regulating devices.

termed, will be more or less cloudy and it is returned through the filter tanks until perfectly clear. After the wort has drained off, three or five extractions with water, depending on the design of filter tank, will entirely remove the sugar. Rapid filtration is a most important step in the process. As the wort comes from the filter tank it is hot and is cooled off to the correct fermentation temperature before going into the large fermentors—large open top vessels provided with aërotors and temperature regulators. The figure clearly shows the succeeding steps.

When molasses is used, a track sump is provided into which tank cars can empty by gravity. From here it is pumped to the boiling tanks on the fourth floor, where it is diluted, acidified and boiled for inversion. If no grain is used, the molasses is then filtered and mixed with organic or inorganic nitrogen compounds and fermented. If grain is used, the unfiltered molasses, after inversion, is mixed in the mash tubs with the grain mash, sometimes



acidified with lactic or sulphuric acid, then filtered and manipulated as already described. The wort, freed of yeast, usually flows by gravity to an underground receptacle, whence it is pumped to the still supply tank and fed to the alcohol stills by gravity.

Most of the yeast factories in this country now use the alcohol obtained for making vinegar. The figure shows the open condenser that the law requires and also the vinegar-mixing tanks and three rows of generators. For the production of vinegar a lower strength alcohol is used than for other purposes. In the latter case an additional still is installed for concentrating the weak alcohol.

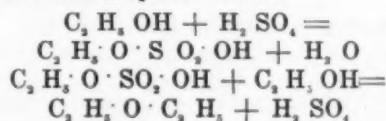
In the production of compressed yeast or in a distillery the most important thing is the seed yeast. With a good, healthy seed yeast, high yields and quality products are obtained. Many use Lindner's pure culture apparatus, which is really a closed top fermenter. After the pure culture yeast has been prepared in the laboratory and cultivated in the yeast jug, it is used to seed the sterilized mash, which has been cooled to the correct temperature in the pure culture yeast machine. The

air is filtered before entering the apparatus, while the gases generated and the air bubbling through the mash are carried off through a pipe submerged in water or oil, eliminating contamination by the outside air.

It is possible to increase the alcohol yield of a yeast factory or the yeast yield of a distillery. In modern distilleries the yeast is recovered and used for cattle fodder or medicinal purposes.

HOW ETHER IS PRODUCED

The diagram, Fig. 2, shows a complete motor alcohol plant with ether plant included. The alcohol flows by gravity into a pure lead or lead-lined steel generator, containing two or three concentric lead heating coils, which may be operated together or separately. Sulphuric acid is blown to a supply tank, and then fed by gravity to the ether generator. If alcohol is boiled in the presence of sulphuric acid, ethyl sulphuric acid and water are produced. The ethyl sulphuric acid reacts with alcohol then, producing ether and sulphuric acid:



Usually, 5 parts 90 per cent alcohol per volume is mixed with 9 parts concentrated sulphuric acid and heated to 130 to 140 deg. C. At this point ether and water distill over and by a continual flow of alcohol into the still the process is continued in such a manner that the temperature should not fall below 130 deg. C. nor go over 140 deg. C. In the former case unconverted alcohol will go over, while in the latter case ethylene will be produced, causing losses in yield.

In view of the fact that the boiling point of ether is 34.7 deg. C., it is important to have an efficient cold water supply for condensation. Otherwise, especially in the tropics, artificial refrigeration must be used. Some suggest that these difficulties be overcome by absorbing the ether vapors directly in alcohol. In this case the mixture would have a higher boiling point and warmer water could be used.

The great advantage of making alcohol from molasses is that it requires less equipment and a shorter process. This is easily understood by comparing the various plant layouts shown herewith, including Fig. 3, which shows a plant for making alcohol from grain and potatoes.

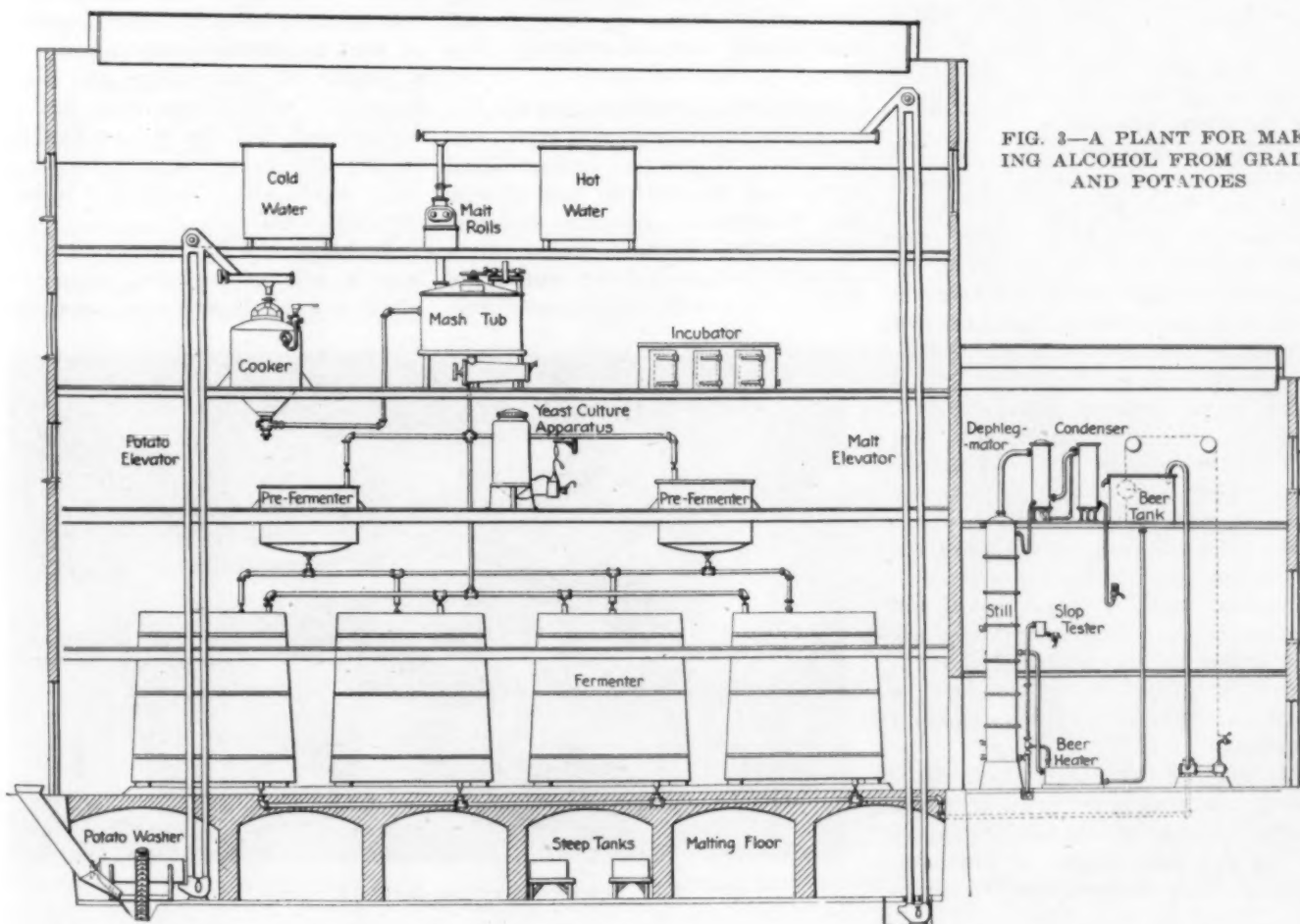


FIG. 3—A PLANT FOR MAKING ALCOHOL FROM GRAIN AND POTATOES



Drying

THE extraction of moisture, whether in part or totally, from various substances used in industry is a process which may be accomplished in many ways. Among the commoner methods are mechanical separation, absorption, adsorption and vaporization. This last is probably the most common in industry and is accomplished in many ways. Some of the systems employed comprise direct and indirect heated kilns and rotary driers; chambers, tunnels or rooms supplied with a current of air by natural or artificial draft, either heat or unheated; spray driers; vacuum driers; and drum driers.

The types of equipment available for accomplishing

drying by vaporization are so numerous that it is impossible to afford space in this issue for a description of them all. For this reason we have confined the discussion which is printed below to a description of the design and operation of the more important types of rotary driers and vacuum driers, as well as equipment which depends for its effectiveness upon the vaporizing power of a current of unsaturated air propelled by fans or blowers. This latter method has perhaps the widest use of any. And, because its successful employment depends on close regulation and control, it is worthy of more careful study than it generally receives from anyone except the builders.

Applications of Drying Equipment

Review of Available Types of Driers, With Particular Emphasis on the Field Covered by Rotary Driers

BY L. R. CHRISTIE

President, L. R. Christie Co., Pittsburgh, Pa.

MANUFACTURERS or producers having occasion to remove moisture from their products will find a surprising variety in types of drying apparatus available. The type selected may mean success or failure of the entire apparatus.

A case recently came to the writer's attention where a manufacturer having material easily filtered and dried in a rotary drier was advised that by spraying his material through heated air he could obtain a finely divided product and eliminate the use of a pulverizer. The heat required to evaporate moisture, which could be taken out by a filter much more economically, was entirely overlooked. A small sample was dried in a laboratory machine and showed very satisfactory results. The process did not work out on a commercial scale and after considerable loss of time, sales and money, a filter and rotary drier are being put in and the drier selected gives a finely divided product so that no pulverizer is necessary anyway.

In another instance, a sticky filter press cake was being dried on steam coils because of its dusty nature when dry and danger of discoloration at high temperature. A prop-

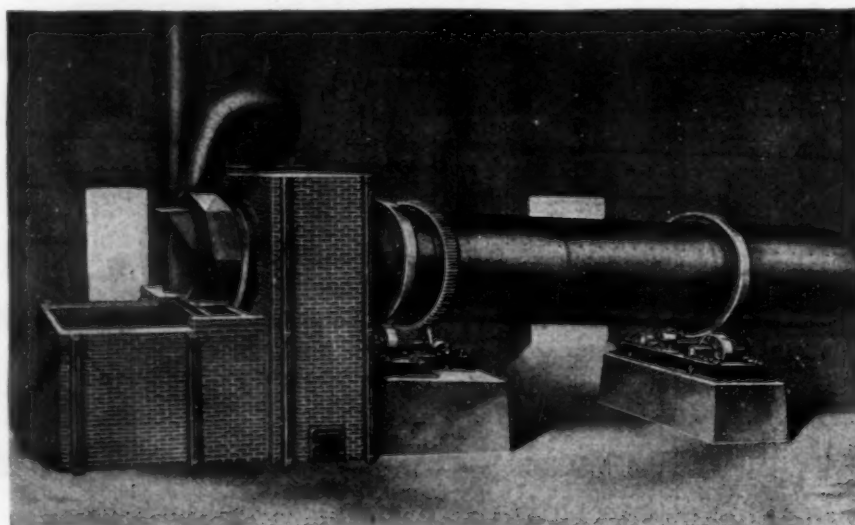
erly selected rotary drier using high furnace temperatures fulfilled every requirement, delivering a dry powder economically and eliminating nine men.

And again a producer, fearing discoloration of his material from contact with furnace gases, asked quotations on indirect heat driers. An examination of his material showed that furnace gases in a properly designed drier would not discolor his product and about double

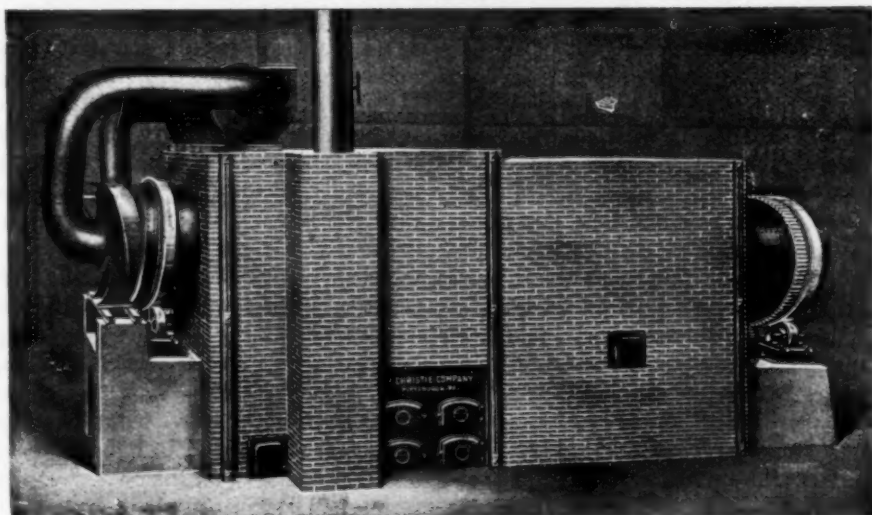
capacity could be obtained for the same initial cost and two-thirds of the operating cost. The producer was naturally elated when the drier was put in successful operation.

The generally accepted theory of drying is to pass a sufficient quantity of air over the material to absorb or carry the moisture; it is sometimes overlooked that there must also be supplied a sufficient quantity of heat to produce evaporation. As a matter of fact, driers are being commonly used where heat and no air is used, but the writer has yet to see and never expects to see a drier where air without heat is successfully used.

Probably the first artificial drier was a pile of material supported above a fire. It was soon apparent,



CENTRAL TUBE ROTARY DRIER



DUSTLESS TYPE DRIER

however, that by tumbling the material around in a rotary cylinder, above a fire, the drying was much more rapid and to induce air and finally the furnace gases through the material was quickly found to be decidedly better. Then came a series of special designs to increase heating surfaces, pass the hot gases partly through the material and partly around the outside and finally through a central tube and return through the material.

CENTRAL TUBE TYPE DIRECT HEAT DRIER

All of these direct heat driers tend to discolor the material, produce dust and some to overheat. Overheating the material is a waste, even if the product is not injured, as it requires more fuel than is necessary for the primary object—evaporation. The central tube type is the least objectionable in these particulars and when properly designed delivers a substantially cool product. The gases enter the center tube at the feed or wet end of the unit, passing to the dry end, where they turn and pass back through the space between center tube and containing drum in counter direction to the material which is in the same space.

The heat being introduced at the wet end inside of the central tube is surrounded by the wet material, which prevents radiation losses and also protects the plates against overheating. As originally constructed, there was not sufficient surface to the central tube, and the gases reached the discharge end at a comparatively high temperature, heating the material unnecessarily and

permitting some radiation loss at this point. The weakness has been overcome recently by so shaping the tube that the surface is increased without increasing the sectional area. This change in construction also permits easier access to the drying compartment for repairs or inspection.

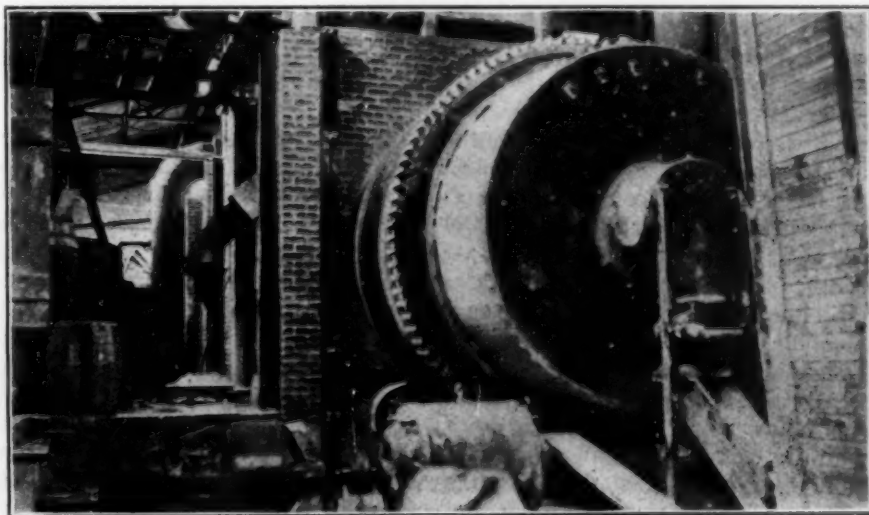
The first cost of this type drier is necessarily greater, but the cost of setting is less than the other improved driers and operating costs considerably less.

PREVENTING DUSTING IN DIRECT HEAT DRIERS

It is sometimes objectionable for the furnace gases to come in contact with the material, which led to the development of indirect heat driers and steam tubular driers, wherein air is induced through the material to accelerate the drying, but furnace

gases are kept absolutely away. The steam tubular driers are very effective when a uniform temperature of between 220 and 350 deg. F. is essential, but the capacity is small per size of unit on account of the low temperature. Both of these machines still have the objection of blowing out dust. Recently an indirect heat drier has been developed which uses high temperature, giving reasonable capacity per size of unit and in place of using air to carry out the moisture a high-pressure fan is used which creates a slight vacuum within the drying compartment and practically no dust is carried out even when drying the most finely divided materials.

The drying drum is subdivided into several compartments, each being surrounded by hot gases, thereby obtaining a very large heating surface. For the same reason the entire drum is inclosed in a brick setting so as to utilize the surface of the outer shell. The feed inlet and discharge outlet, while continuous in operation, are arranged to prevent any material flow of air and the only medium for carrying out dust is the evaporation moisture. The volume of this is so slight even when drying high-moisture materials that it has relatively no velocity through the drum, and at the dry end, where the material is dusty, there is no moisture given off, hence nothing to carry the dust. The greatest volume of moisture is necessarily at the wet end, and this has the merit of preventing case-hardening, facilitating drying and in most cases the material is discharged as a cool dry powder.



INSTALLATION OF DUSTLESS TYPE DRIER



When it is necessary to dry at temperatures below 212 deg. F., either a high-vacuum type of drier must be used or a large volume of low-temperature air must be put through the material. High-vacuum driers are either of the chamber and tray construction, requiring considerable labor, or of the paddle-stirring type, which with certain materials permit a layer to accumulate against the heating surfaces, making an undesirable insulation. Both types are necessarily intermittent in operation and when conditions permit the air-absorption type is more economical. With dusty materials this latter method is impractical unless elaborate systems of dust-collecting apparatus is also

used, but frequently this is to be preferred to the difficulty of maintaining high-vacuum apparatus in good working order.

The fact that these machines work at low temperature does not mean that they save fuel. The latent heat of evaporation increases as the temperature and sensible heat decreases, so that one about offsets the other, and in the vacuum apparatus there are losses in power on account of maintaining the vacuum. The low-temperature air-absorption types are generally more simple to operate and work continuously without delays and expense for repairs. They are generally of single shell construction with steam coil or other means of preheating the air located at

either end depending on the character of material being heated. They are now being made with internal flue and double flow of air.

Spray driers are successfully used for low-temperature work, the principle of operation being to spray a material in solution or suspension into a large chamber, a current of preheated air being also introduced to absorb the moisture, the solids settling to the bottom of the chamber or being caught in dust-collecting apparatus. As evaporation is the most expensive means of removing moisture, it is obviously best to filter or remove mechanically as much water as possible when conditions will permit and then use an approved form of rotary drier.

Drying at Atmospheric Pressure Through Use of Fans

Some Examples Which Explain the Operation of This Type of Driers and a Description of the Various Commercial Machines Available

BY J. M. MATTHEWS, E. E.
Buffalo Forge Co., Buffalo, N. Y.

TO DRY efficiently at atmospheric pressure a fine subdivision of product is necessary to furnish maximum surface. Many materials are placed in trays, while others are piled like lumber or hung up like leather. Between layers or through trays, warmed dry air is passed fast enough to dry the last part of the material it touches as well as the first, since even drying is a necessary requirement. The size of the spaces through which the air passes is determined by experience or experiment and is closely dependent upon the temperature and humidity of the air to be used.

The effect of temperature on the moisture-carrying capacity of the air is marked, varying from 2.84 grains per cubic foot at 4 deg. F. to 58 grains per cubic foot at 140 deg. F. The humidity of the air hastens drying by preventing "case-hardening" of the surface of the material being dried. Such an occurrence imprisons moisture and adds greatly to the drying time required. Only a few materials can stand high humidity during drying without undergoing deterioration. Some, like lumber, have their quality improved by such conditions.

Practice can teach us much, so the

following table from H. C. Russell's American Society of Heating and Ventilating Engineers paper is valuable:

CONDITIONS	FOR DRYING	DIFFERENT
Material	MATERIALS	
	Temp. (Deg. F.)	Drying Period
Sole leather hides	90	4 to 6 days
Thin leather hides	90	2 to 3 days
Bone glue	70 to 90	4 days
Skin glue	70 to 90	2 days
Starch	180 to 200	12 hours
Apples	140 to 180	6 hours
Leaf tobacco	85	
Stem tobacco	200	
Soap	100	2 days
Wool	105	
Rags	180	
Pottery	120	

PROBLEMS WHICH ILLUSTRATE PRINCIPLES

We can proceed to solve a few drying problems before discussing types of driers if we will remember the following: The temperature of the air supplied the drier must make up the heat losses from radiation through the walls; supply the heat for raising the temperature of the material being dried, including the contained moisture as well as that of the trays, trucks or other apparatus used to bring it into the the drier; and the heat needed to evaporate the moisture removed by the air.

The quantity of air to be supplied by the fan must be sufficient to re-

move the desired weight of moisture without bringing the air to saturation at the green end of the drier where the air leaves it. The relative humidity of the air leaving the drier is ordinarily kept below 75 per cent.

The chart shown in Fig. 1, a psychrometric chart, is of value in solving drier problems.

Nine times out of ten what we call drying is really a chemical, biochemical or physical processing in which drying may be but one of the ultimate objects. In air processing the temperatures used vary, usually from 75 to 180 deg. F., and the relative humidity varies from 90 to 15 per cent. The time element is regulated by controlling the temperature and the wet bulb depression. This latter is necessary, as many materials require exposure to a series of different conditions, as will be shown in the lumber problem to be taken up later.

At the beginning of the process, when the relative humidity reaches 80 per cent or more, the free moisture is being removed and most hygroscopic substances possess their maximum plasticity or elasticity. After the free moisture is removed, only a part of the hygroscopic moisture is removed, as taking it all out would cause an injurious physical change in the material. Thus several stages in which the rate of moisture removal is controlled in accordance with the successive conditions of the material as it dries must be exactly maintained with extreme accuracy.

Lumber is dried in "Cutler" dry kilns in 5 to 7 days instead of 25 to 36 days by following the above prin-



ciples. The lumber, 4x4 in., is divided into layers by 1-in. spacer sticks—care being taken to dry the following varieties at one time: Ash, basswood, beech, birch, chestnut, cucumber, elm, gum, maple, poplar, sycamore, tupelo and willow; and to dry at another time cherry, hickory, locust, mahogany, red oak, white oak and walnut.

Both these groups of lumber are steamed for 4 hours, the first at 150 deg. F., and the latter at 140 deg. F.; after which the temperature is gradually increased day by day with short steaming periods. This is carried on until the fifth day for the first group and until the seventh for the second group. After this the moisture content should have been reduced from 25 per cent to 6 per cent.

By recirculating the air in this kiln after it has given up moisture to condenser curtain a very large fuel economy is obtained. This kiln construction will be covered later. Many unexpected advantages accompany properly conducted drying operations such as a great saving in expensive roofs, carriers and containers, which do not have to be renewed nearly as often where drying is properly done and vapors are confined.

DRYING OF PAPER, SUGAR AND COPRA

By blowing warm air through nozzles onto felts carrying paper in paper machines it is possible to prevent uneven drying and breakage of

paper, increase its strength by drying at lower temperatures, save over 10 per cent steam consumption per lb. of paper, and get a saving in felts that will pay for the installation in a few years. A 30 to 40 per cent less steam pressure needed means a saving in maintenance of steam lines, packing, and so on. An increase of speed of machines is possible, giving greater production, and better paper is made.

The average run of purged sugar leaving the centrifugals contains 4 per cent moisture by weight, or 280 grains per lb. To get 2,000 lb. dry sugar per hour, we must handle 2,000 divided by 0.96, or 2,083½ lb., the moisture being 83½ lb. per hour.

With 7,000 grains per lb. of water this amount equals 583,333 grains to be removed per hour, or 9,717 per minute. A good average condition for air entering the heater upon which to base calculations is 80 deg. F. and 50 per cent humidity. Referring to the chart in Fig. 1, we have 77 grains per lb. of air and 13.85 cu.ft. per lb. of air. This gives 5.56 grains of moisture in each cu.ft. of air to start with.

Test records show two sections of Buffalo standard pipe coil heaters, when served with steam at 65 lb. pressure and air at 850 cu.ft. per minute, will raise the temperature of the latter from 80 to 131 deg. F.

Figuring that we shall be able to raise the humidity to 70 per cent in passing through the drier, we find

on looking at the chart that our air condition will be 88.5 deg. F. dry bulb and 80.5 deg. wet bulb. It will contain 145 grains of moisture per lb. of dry air and run 14.3 cu.ft. per lb. at this condition.

Subtracting 77 from 145 gives us 68 for the grains of moisture per lb. absorbed. Dividing by 143 gives us 4.75 grains per cu.ft. Again dividing this into 9,717 grains of moisture per minute to be removed, we get 2,050 cu.ft. of air per minute at 88.5 deg. F. temperature leaving drier. Increasing volume for 130 deg. F. gives 2,210 cu.ft.

Copra, or coconut meat, is dried in two stages. The first stage, from 50 per cent to 40 per cent moisture, separates the meat from the shell. Then the meat is dried at a temperature under 95 deg. C. (to retain the oil chemically unchanged) by the use of pure, hot air, as waste gas drying would discolor and impart a smoky taste to the material. This material is placed in thin layers and moved against a current of warm air.

SOME TYPES OF DRIERS USED

Driers having a temperature below the boiling point are classed as low-temperature driers, while those having temperatures above the boiling point are known as high-temperature driers. The first class are heated with steam or hot water. The latter class are heated with electricity, heated oil, direct introduction of flue gases, high-pressure steam or flue air heaters.

High-temperature driers are used largely for drying high-temperature siccative coatings, varnishes, enamels and paints—where there is little moisture to be evaporated. In both types of driers the saturated or partly saturated air next to the material being dried must be removed by the use of fans, or drying ceases and in some cases explosive mixtures are formed. Slower results can be obtained by removing the air by natural draft; but this method precludes the economies of recirculation as well as greatly lengthening the time required.

Rapid air circulation was neglected in the early types of drying kilns, which were simply heated rooms with coils or radiators around the sides near the floor. A vent for moist air was provided near the ceiling or at the ceiling, where much of the heated air could escape without exerting any drying effect. In these the material dried most near the radiators and

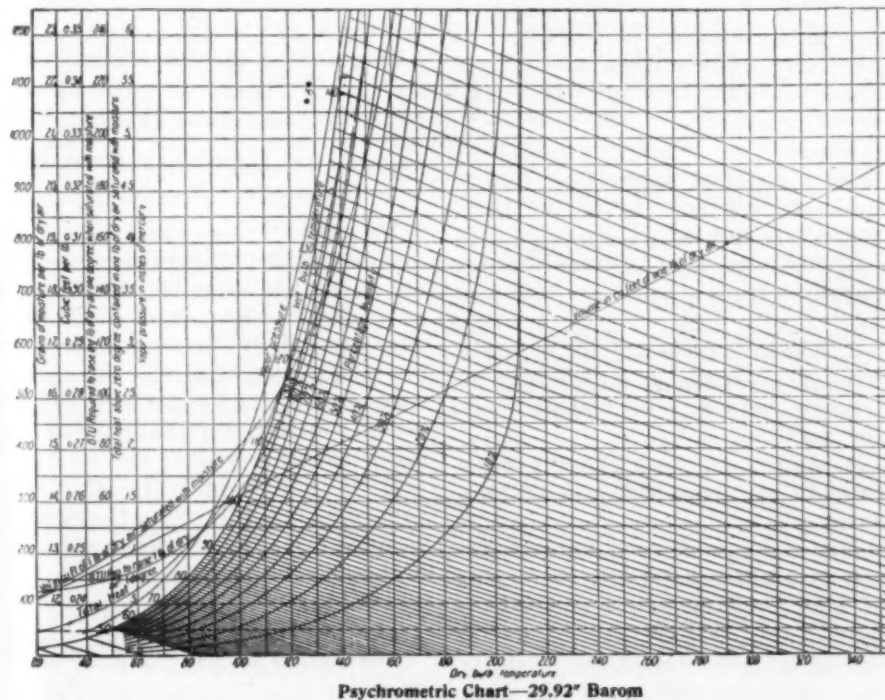


FIG. 1—PSYCHROMETRIC CHART—29.92 INCHES BAROMETER
Copyright Buffalo Forge Co.



least in the center and near the floor, and an uneven product resulted.

In another type the coils were placed below the floor and the cooler air near the roof passed down behind a baffle to condenser coils. In this type there is also a stagnant area at the center of the pile or stack of trays. Other types have heater coils behind partitions with circulation caused by water spray.

One type, the operation of which was noted above in the problem on lumber drying, has heater coils in a tunnel under the floor. The heat rises between the piles and is kept from going over the top by curtains. After passing through the piles, the hot air is robbed of its moisture by curtains which form the sides. The air is recirculated and the curtains are dried off on the other side by natural draft air currents. The rate of moisture removal can be controlled in this type by the amount of ventilation on the outside surface of the curtain.

USING FANS IN DRIERS

The early types of fan driers in the form of tunnels showed a marked tendency for the air blown in at one end to stratify on its way to the other end. With the hot air at the top drying was not uniform. This was overcome by blowing the air cross-ways through a large number of openings; but the ensuing complication became costly.

In driers having a main supply pipe under the floor with branches to either side the air spreads in all directions under the material and is exhausted, usually, at the top.

In another type of drier, the air is blown to the floor on one side of the room, passed horizontally through the materials to be dried and is exhausted near the floor on the other side. Driers having a perforated floor with diffusing chamber beneath and a large number of small openings in the floor are efficient when a large fan is used and the larger part of the heated air is recirculated. A somewhat more efficient type of drier has the heated air supplied through a perforated ceiling. It is exhausted through a floor grating. A smaller quantity of air is required for this type and the efficiency is higher; but the upper part of the material dries more rapidly than that near the floor.

Perforated side-wall kilns, where the air is blown across the material, give somewhat better results. Some

kilns have mechanically operated deflectors to distribute the air across the trays and are efficient when large amounts of air are handled and recirculated. Where air is passed back and forth through trays and reheated before each pass, high efficiency results as well as a uniform rate of drying.

Those kilns which use disk wheels or propeller fans to circulate the air in the kiln—through the material, over heated coils, through a false ceiling and back through the material—are efficient because the air is used over and over again, part being taken away by a stack or small ventilating fan. But they are apt to be expensive because of waste space and because the fans which are

employed do not give the best efficiency.

In the ejector system drier of the Carrier Engineering Co., a fan forces warm air through specially designed ejector nozzles and induces a circulation within the kilns of from three to five times as much air as passes through the nozzles. The air is conditioned by a Carrier "dew-point" control at the fan so all the air is brought to a definite point of saturation and then reheated to maintain a definite room temperature. Or else the control may be regulated by the admixture of fresh and return air, controlled by a hygrometer placed in the room. In either system, a very accurate humidity control can be secured.

Vacuum Drying

For Materials Which Must Be Dried at Low Temperatures, Often Under Non-Oxidizing Conditions, There Have Been Developed Several Distinct Types of Equipment

BY GRAHAM DEVINE

J. P. Devine Co., Buffalo, N. Y.

VACUUM drying was introduced in this country about 20 years ago, and in that comparatively short time it has become almost indispensable in every known industry in which time, temperature and oxidization are factors in the drying of different materials.

Drying, as the term is generally understood, means to remove moisture from a solid material; vacuum drying means the evaporation of moisture or any volatile solvent from either a liquid or a solid under reduced pressure.

Drying, or removing moisture from a material, depends on supplying sufficient heat units for three distinct purposes:

1. Sufficient heat to transform the moisture from a liquid or solid to a vapor.

2. The heat necessary for the molecules to overcome intermolecular attraction between the moisture and the material.

3. Additional heat for the molecules to overcome atmospheric pressure.

The elements of time, temperature and oxidization enter into the drying of almost all materials and this is particularly true in regard to the drying of pharmaceutical products, the many ingredients of the complicated dye and color industry, electric coils and cables, armatures and

high explosives, fruits and fruit juices, and similar materials.

In drying materials that are delicate and sensitive to heat, the apparatus can be operated under a very high vacuum within 1 or 2 mm. of the barometer, thereby reducing the boiling point of water to less than 50 deg. F., and solvents to a correspondingly lower temperature. This makes it possible to use circulating hot water as a heating medium, the temperature of the water being below the danger point of injuring the material that is being dried.

AUXILIARY EQUIPMENT MUST BE PROPERLY BALANCED

Vacuum drying has often been condemned and discarded as having no advantage over drying in the atmosphere when the conclusions were absolutely erroneous because the auxiliaries, such as condenser, vacuum pump and vapor connections, were unsuitable for the drier of the material being dried.

It is most important that the auxiliaries used in connection with a vacuum drier, of whatever type, be properly balanced, the deciding factors being:

- The heating surface of the drier.
- The nature of the material being dried.

- The per cent of moisture or solvents contained in the material.



The weight of the material per cubic foot.

The number of hours for operation.

The maximum temperature permissible in drying any particular material.

With these facts at hand, the number of square feet of heating surface necessary to handle either a solid or a liquid in a given number of hours can be determined. The maximum temperature permissible in drying the material, together with the nature of the material, determines the heating medium, and these two factors determine the amount of vapor that can be driven off from the material in a given time under any decreased pressure or vacuum.

With the amount of vapors determined, the size of the vapor pipe can be calculated, and if the speed of the vapors is too fast, the efficiency of the condenser is affected. If the cooling surface of the condenser is not adequate and of the proper design for taking care of the maximum amount of moisture that is driven off in the form of vapors from the material being dried, it will be impossible to maintain the highest vacuum and the drying time will be prolonged, thereby increasing the temperature to which the material being dried is subjected.

This is also true in regard to the vacuum pump; if the pump is not large enough to remove the air from the apparatus and the air from the vapors given off from the material being dried, it will be impossible to obtain the highest vacuum. If a larger pump than is necessary is installed, it means an additional expense for the power required to operate the vacuum pump.

Therefore there is no necessity for any rule-of-thumb calculations in determining the auxiliaries for a properly designed vacuum drying apparatus, as all of the above determining factors can be calculated accurately.

ADVANTAGES

Vacuum drying has the following advantages:

1. The removal of moisture or solvents from a material with the minimum of heat units; this is an important item at the present price of fuel.

2. The rapidity of drying.

3. The elimination of high temperatures during the drying process.

4. The prevention of oxidization of the material while being dried.

5. The prevention of discoloration during the drying period.

6. The elimination of odors.

7. The flexibility of the apparatus permits the production of a bone-dry material or the drying process may be discontinued with any per cent of moisture or solvent desired in the finished material.

8. The saving of factory space.

9. The elimination of fire hazards.

10. The production of a uniform product from day to day.

11. The recovery of solvents at the minimum of expense.

with observation glasses for inspecting the material during the drying period.

The heating shelves are made of hydraulically straightened sheet steel plates, welded at the edges and supported by machined spacers, with countersunk rivets at regular intervals. The heating shelves are made to withstand a test pressure of 100 to 150 lb. per sq.in.; the holes are drilled and countersunk. Each heating shelf has its steam inlet and outlet connections, with expansion bends for complete drainage of the condensed steam or hot water, and to take care of the expansion and contraction.

In operating a vacuum chamber drier it is possible to eliminate any possibility of the material being dried at a temperature higher than the boiling point of water or solvents; this being determined by the vacuum maintained on the apparatus in the following manner:

The material to be dried is placed on the trays; these are arranged in the drier; the door is closed and the highest possible vacuum obtained. Then turn on the heating medium, whether it is steam or hot water, and continue the drying until the condensed vapors cease to drop in the condenser; shut off the steam or hot water and finish drying or removing the last per cents of water with the heat remaining in the material. In that way you eliminate all possibility of raising the temperature of the material being dried beyond the boiling point of water in whatever vacuum is maintained on the apparatus.

ROTARY VACUUM DRIERS

As shown in Fig. 2, the rotary vacuum drier consists of a steam-jacketed outer cylinder with an interior, rotating heating tube to which is attached adjustable stirring blades of very rigid construction, and is especially adapted to dry materials that can be stirred or agitated during the drying process. The material to be dried is kept in constant motion, bringing new particles of the material in contact with the heating surface, and in that way the drying time is greatly reduced and a much larger quantity can be handled per charge.

When drying material which has a tendency to coat the heating sur-

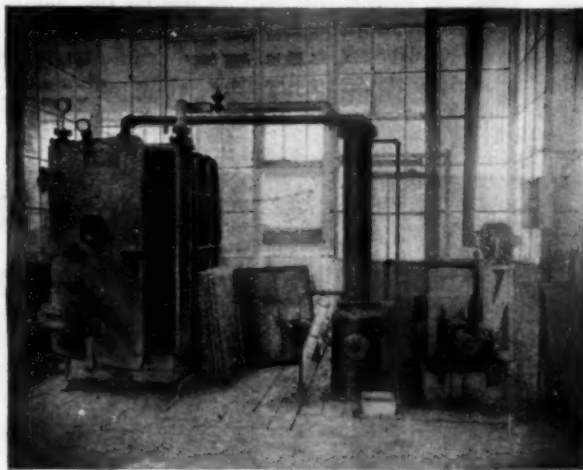


FIG. 1—VACUUM CHAMBER DRIER

There are many types of vacuum driers, but four of the most general types are: Vacuum chamber drier; rotary vacuum drier; vacuum drum drier, both single and double; vacuum drier and impregnator.

VACUUM CHAMBER DRIER

Chamber driers are of two general types—i.e., the rectangular and cylindrical; the outer casing of the former is made of cast iron, while that of the latter is made of sheet steel. The heating shelves are arranged either horizontally or vertically.

Fig. 1 shows a vacuum chamber drier, consisting of a heavily ribbed cast-iron box with one or more sections; the doors are made of cast iron, and are attached to the body of the drier by double swing hinges. The drier is made airtight by a rubber gasket fitted into a groove on the inside flange. When solvents are used the flange is machined with a V-shaped lip and a lead or asbestos gasket is used. The doors are fitted



face, the apparatus is installed with adjustable scrapers to prevent this condition arising during the time of drying. Rotary vacuum driers, when the quantity is large enough, can be made continuous in operation, but these auxiliaries are not considered except for very large quantities of granular or powdered materials.

VACUUM DRUM DRIERS

The vacuum drum drier is used for drying a material in liquid or semi-liquid form, with which you can obtain a film on the drums. There are two general types of vacuum drum driers, the single and double type. The single vacuum drum drier, as shown in Fig. 3, consists of an outer cast-iron casing, inside of which rotates a hollow drum made of cast iron, grone, gun-metal, aluminum, Monel metal or other materials. The drums are

of the drums and consequently the material would bake and solidify and thereby injure the finished material. When drying a material which is delicate and sensitive to heat, a film can be placed on the drum by a small feed roller. The material is fed from a cooled liquor trough to the feed roller and thence to the large drying drum. In this way the material does not come in contact with any heating surface before it reaches the drum proper.

The above described methods are the most efficient and simplest way of placing a film on the drum drier at the bottom of the drum.

A more recent development for some particular materials is the top feed, in which the film is placed on the drum at the top of the drum. This requires a specially constructed trough with an adjustable roller and end shield rings to prevent the mate-

apparatus with effervescing materials, which is not possible in the single type. The double type can be made continuous or intermittent in operation.

Vacuum drying and impregnating may be combined in an apparatus consisting of a horizontal or vertical chamber, with either steam jackets or welded endless coils for steam or circulating hot oil where it is necessary to liquefy a compound having a liquefying point higher than the temperature of steam available; a compound or liquefying tank, steam-jacketed or with endless welded coils, for the same purpose as explained for the drying and impregnating chamber. The two vessels are connected by steam-jacketed pipes and steam-jacketed valves to prevent the material from solidifying. The method of operation is to place the material to be dried and

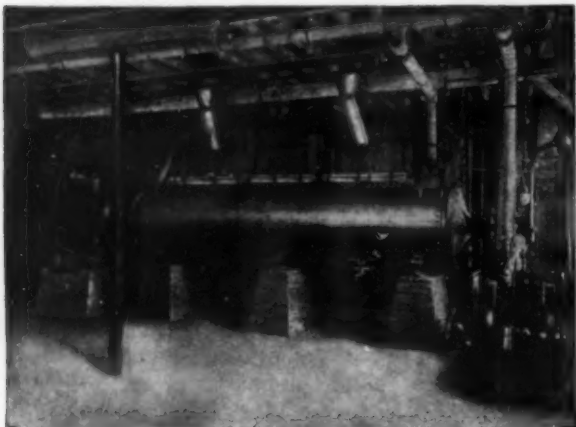


FIG. 2—ROTARY VACUUM DRIER

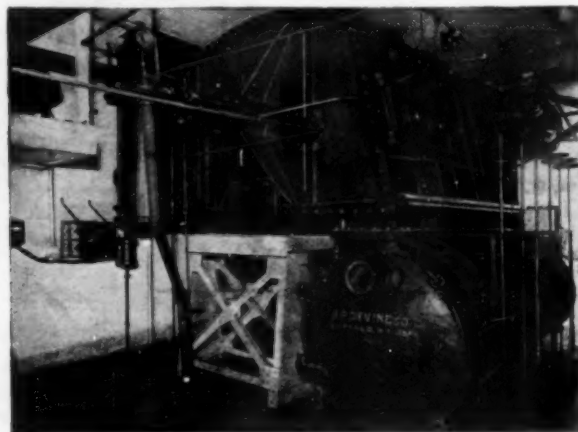


FIG. 3—SINGLE VACUUM DRUM DRIER

properly balanced, machined, ground and polished over their entire heating surfaces, and heated internally with hot water or steam and where high temperatures are necessary, circulating hot oil, and a still higher temperature, internal combustion, may be employed. The material to be dried is placed on the single vacuum drier in various ways, and this is most important to obtain the maximum capacity of the drier and a uniform dried product.

The simplest method to place a film on the drum is to dip the drum into the material, which is automatically regulated and kept at a constant level. This method cannot be employed successfully except when the drum is provided with adjustable shield-rings to prevent the material from solidifying on the ends of the drums, as the scraping knives do not come in contact with the ends

of the drums and consequently the material would bake and solidify and thereby injure the finished material.

The vacuum double drum drier is constructed on lines similar to the single vacuum drum drier, but it is of more recent development. It consists of two drums, rotating in opposite directions, an adjustable knife, with knife holders for removing the dried material, agitators when necessary, to prevent the material from solidifying. This type of construction has many advantages over the single drum drier, as a larger quantity of material can be handled in a smaller apparatus. Semi-liquids as well as liquid materials can be dried in this type of machine, and it can be used for drying material which has a tendency to effervesce through the drying period, as the dome on the top permits the operation of the

impregnated in the impregnating chamber, where the air and moisture in the material are rapidly removed. The liquefied compound is now drawn into the vacuum chamber, and on account of the absence of air and moisture the compound immediately penetrates the innermost recesses of the material and in the shortest possible time. When drying and impregnating electric coils and cables, the operator is limited to a temperature that will not char or injure the insulation of the coils or cables and it is absolutely necessary that the least trace of air or moisture be removed. It is very often necessary to operate the entire apparatus under a vacuum within $\frac{1}{2}$ in. of the barometer.

The above types of apparatus, in modified forms, are used for the impregnating of a great variety of materials.



Crystallization

THE chemical engineering industries are requested to blush with as much apologetic grace as they can muster. A large percentage of material produced by them are crystallized products, and yet a modern technology of crystallization is almost non-existent. Fortunately we have the sugar industry, in which the technique of crystallization has been excellently worked out, and we have also individual engineers who have occasionally worked out processes like the Walker-Swenson process. Without such we should hardly be able to hold up our heads. Crystallization is like a poor relation. It comes along at the end of a process after expensive furnaces, reactors, evaporators and conveyors have been selected and the money available for the installation has largely been allotted to this earlier equipment. So the tendency is to say, "Oh, get a couple of tanks or vats, the stuff will crystallize all right." So it probably will, but by that same token your operating costs will go up. Suppose the saturated solution is run into a vat and allowed to crystallize. It is necessary to remove the crystals from the tank by hand. A nice inconvenient expensive operating expense, but that is precisely what is happening in literally hundreds of otherwise well-operated plants.

Part of the trouble lies with the position of the process in the production sequence as already stated, but part of it lies in the lack of attention to the fundamental principles of precipitation and crystallization. Perhaps the simplest exposition of these principles can be found in an excellent book on the Chemistry of Colloids, by W. W. Taylor (Longmans) in the discussion of Von Weimarn's theory of the

production of colloidal solutions. Von Weimarn's contribution to the subject of colloids is distinguished and in enunciating the conditions favoring the preparation of colloidal solutions he has emphasized most dramatically the laws of crystal formation and crystal growth.

The size of a crystal depends upon two things: first, upon the initial condensation of crystal units, and second, upon growth of these units either by aggregation or deposition of solute from the solution.

Quantitative equations have been developed covering both processes, but it is unnecessary in a consideration of problems of plant operation to do more than analyze the forces at work. Particle size is of great importance also where precipitation occurs and very different results can be obtained on a plant scale by varying conditions of precipitation. The same factors operate in these cases also as in the case of crystallization.

Condensation pressure and condensation resistance are accurate terms for concentration (supersaturation) and solubility. These are the factors controlling precipitation. Increasing the supersaturation has the same effect on particle size as decreasing the solubility of the solute. And crystal growth follows a simple arithmetical formula involving such factors as surface of the crystal phase, concentration, solubility, supersaturation, etc. If production men would only consider these principles and then apply them, together with the same efficiency standards that are applied to other unit processes, crystallization technique would be a credit to the industries and the dividends resulting from such consideration might have a desirable effect on salaries.

Crystallization

A Brief Survey of Methods Which Have Been Employed— A Discussion of Modern Developments, Including a New Crystallizer

BY GEORGE T. WALKER

Consulting Chemical Engineer, Minneapolis, Minn.

A STUDY of the methods and equipment which have been employed for crystallization shows that, while it is an important step in many chemical processes, very little has ever been done toward the production of equipment to increase and control production at this point. We have a great variety of filters, evaporators, driers, etc., to choose from, but we seldom see crystallizers mentioned, and if one is to be purchased there are no data to show how many of a given type will be required for the desired capacity, although most other items of equipment can be purchased on a capacity basis.

This is partly because the need for such equipment is not very apparent in laboratory and semi-commercial tests. Nothing could be simpler than to allow crystallization to occur spontaneously in a beaker or flask, or possibly in a 5- or 10-gal. jar. If haste is desirable, probably such a container will be immersed in cold water. This crystallization is apt to be the last stage in the process, hence, if results have been favorable up to this point, it will probably be advanced to full-sized factory equipment. No provision will be made for a mechanical crystallizer. Why should there be? If the solution is

stored in a tank or vat of wood or steel, perhaps lead- or enamel-lined, and we let "nature take its course," crystals will be formed without any attention. What more could be desired? Some such line of reasoning must account for the very general use of such equipment.

But the use of vats brings up a number of more or less serious difficulties. First, and often worst, most if not all substances that will crystallize when a saturated solution is cooled have a negative heat of solution—i.e., they absorb heat while dissolving—and conversely, when the solution is cooled, a like amount of heat is liberated. This may be called the latent heat of crystallization and is very generally on the order of 100 B.t.u. per pound of crystals formed. It must be figured on the hydrated basis where water of crystallization is present. This may not seem such a very large amount of heat to be



removed, but it is in addition to the heat given out in the cooling of the solution and is very often greater than the sensible heat in actual quantity, and in many cases is given off at a temperature only slightly higher than that of the surrounding atmosphere. Then the rate of cooling may be as slow as it would be if the specific heat of the solution were several times that of water, although in fact it is always less than unity. This explains the fact that the contents of crystallizing vats will have an almost constant temperature for many hours or even several days while the crystals are forming.

Many of these crystals form on the sides of the vat and insulation increases as crystallization goes on until the upper surface is the only one where cooling occurs. Is it any wonder that hot weather decreases production and sometimes stops it entirely?

SOME OPERATING DIFFICULTIES

If the solution has not been perfectly filtered, or if cooling or contact with the air causes impurities to separate, the suspended matter will settle and contaminate the crystals. This is favored by the decreasing gravity of the mother liquor as crystallization goes on. Sometimes this is avoided by suspending in the solution strings or strips of a suitable metal or of wood on which large crystals develop free from such contamination. These crystals are purer than the fine material removed from

the bottom of the vat, which probably accounts for the general impression that large crystals are the best, so that the finer "bottom crystals" must be re-run or sold at a lower price. This method probably speeds up crystallization by furnishing additional surfaces for crystal growth so that insulation of the side walls does not occur so soon. However, slow cooling is so desirable in the production of fine large crystals that the vats are often insulated intentionally to decrease the rate of cooling.

A great deal of work, mostly empirical, has been done to determine just what conditions are best suited for the development of such crystals, and the demand for them has overshadowed the fact that small crystals, if pure, are generally far more desirable. The consumer nearly always puts crystals into solution—e.g., glaube's salt in dye-baths—or mixes them with other materials in the dry state—e.g., the preparation of washing and cleaning compounds. In either case crushing is necessary for the best results.

In some such cases where only small crystals are desired, the fragments produced by crushing large masses are not acceptable. In order to produce such crystals dilute solutions are employed so that the formation of crystals is delayed until the solution is nearly cold and but little crystal growth occurs. But this greatly decreases the production per vat and increases the amount of fuel required for the process, as a much

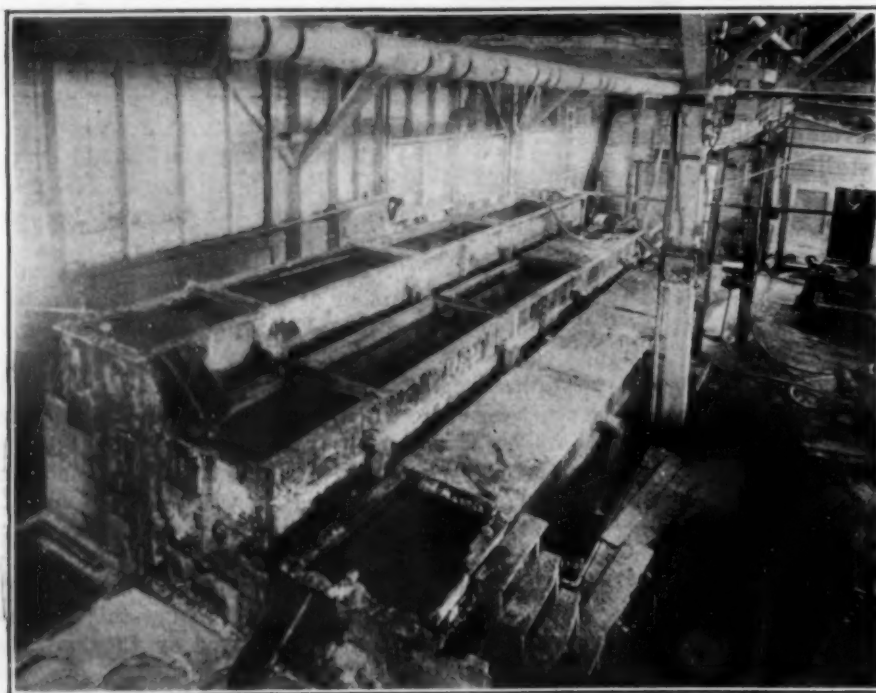
larger amount of liquor must be cooled to produce a given weight of crystals, and therefore a larger amount of mother liquor must be heated to the boiling point before it can be evaporated for return to process.

In any case when crystallization is completed the mother liquor is drained off and the crystals are stripped from suspended strips or strings while those in the bottom are dug out with pick and shovel. They may be piled in heaps for drainage or whirled in a centrifugal. This method of removing the crystals requires a large amount of manual labor and the product is subjected to gross contamination. In a large installation of this kind a great deal of conveying equipment is required to bring the product to some central point for centrifuging, drying and packing. The space occupied may be greater than that required for the entire plant aside from the crystallizing department.

EFFECT OF AGITATION

Every chemist knows that agitation to cause the formation of fine crystals is necessary in analytical work and in the preparation of salts where high purity is essential. Evidently the same principle would apply in large-scale fractional crystallization. We also know that rapid cooling favors the formation of small crystals. One of the simplest methods of accomplishing both agitation and cooling in tanks is the use of compressed air. In this case cooling will proceed rapidly while the liquid is hot, as both evaporation and a large temperature difference enable a moderate volume of air to remove a considerable amount of heat. In the later part of the process evaporation is a very small factor and the temperature of the cooling air will be close to that of the liquid unless the air is artificially cooled, which would be very expensive. The use of a volume of air sufficient to cause rapid cooling will generally stir the liquid so rapidly that the crystals will be too fine for convenient handling. In any case the use of compressed air is an expensive method of agitating and cooling in comparison with the use of mechanical agitators and water cooling.

In order to hasten crystallization in vats coils have been used, which are supplied with cold water or even with refrigerated brine. These hasten cooling in the earlier stages,



WALKER-SWENSON CRYSTALLIZER IN OPERATION



but later the formation of a coating of crystals insulates them until they are practically useless and the crystallization is completed by air alone. In the case of fractional crystallization, coils only make matters worse since the liquor surrounding them will be cooled below the desired temperature before the main body is cool enough to deposit its load of the product desired.

BETWEEN SCYLLA AND CHARYBDIS

The use of a rapidly revolving stirrer in the tank may keep the coils free from crystals and greatly hasten cooling, but in many cases the rapid agitation required will produce extremely fine crystals. The process is not continuous, but it can be applied to fractional crystallization if carefully supervised.

Another plan involves the use of coils, made up with return bends, through which the cooling medium flows while the liquor flows down over the outer surface. For these surface coolers some means must be provided for the continuous or periodic removal of the crystals. The crystals are very irregular in size and form and the apparatus is best adapted for cases where the yield of crystals is small and they are to be removed from the liquor in order to purify it rather than for the sake of the crystals. This arrangement would not be at all suited for fractional crystallization.

Apparently one of the simplest methods of mechanical crystallizing would be to use a water-jacketed screw conveyer. Such equipment is used in cooling oil to remove paraffin wax. This idea has often been tried for crystallization but generally with very little if any success. The spiral merely scrapes off the layer formed on the cooled surface and rapidly carries it to the discharge end without any chance for crystal growth. This principle is desirable in some cases, such as the freezing of ice cream, where any formation of grain is very undesirable.

The Swenson-Walker crystallizer,* probably the first successful machine adapted for continuous crystallization of inorganic compounds, is a modified form of the jacketed screw conveyor, with a triple ribbon screw of extremely long pitch, revolving at a low speed. While it gradually carries the crystals forward, its main purpose is to lift them to the surface

and allow them to fall gradually through the solution. Each crystal is lifted hundreds of times during the period of 8 to 24 hours required for the passage of material through the machine. At the same time they are being gradually carried into cooler solutions of gradually decreasing concentration but always supersaturated. This supersaturation must be very slight on account of the solid phase that is present and the gradual stirring produced by the spiral.

It would be natural to assume that crystals will form on the cooled walls of the machine and be broken off by the blades as they pass. That this is not the case is shown by the small amount of power required and, more strikingly, by the fact that the crystals are generally perfect specimens, with all faces symmetrically developed, and not mere fragments. In fact the crystals grow while in suspension during a long period of time, although feed to and discharge from the machine are continuous.

Cooling water is passed through the jacket counter-current to the flow of the solution through the machine, and an effective system of baffling gives it a high velocity so that heat transfer is rapid, although the water consumption is low.

This machine eliminates all manual labor in connection with crystallization. One operator can attend several of them, each of which may be producing from 10 to 30 tons of crystals per 24 hours. They may all be operated on the same product or on

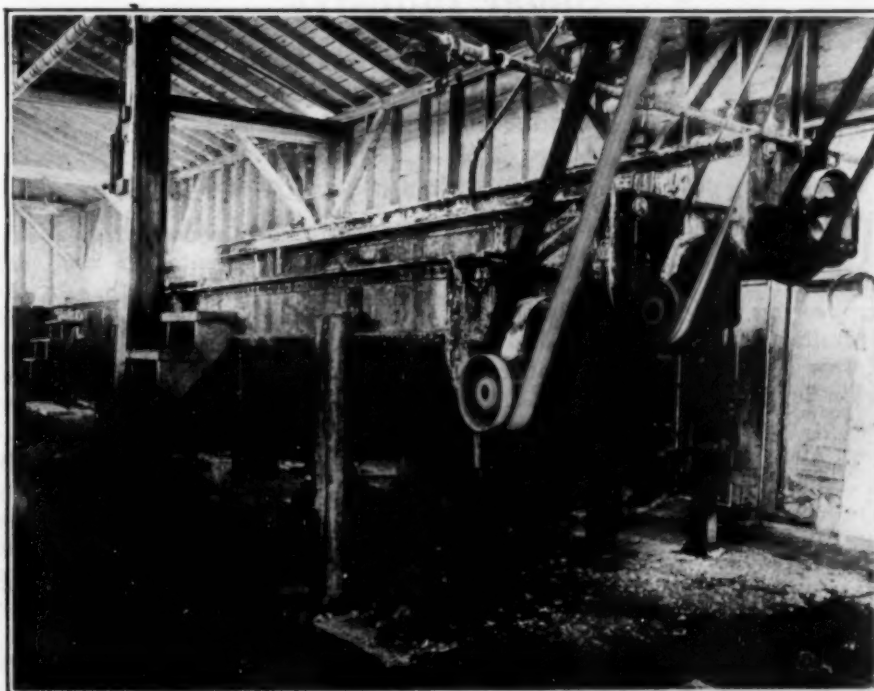
different materials as desired. In the case of a single machine this duty can be assigned to the man who attends to other machines in the same department.

The discharge temperature can be governed by the rate of flow of the cooling water or, preferably, by the rate of feed, which may be controlled manually or by means of a thermostat at the discharge end which controls a valve in the feed line so that the rate of feed will increase with a drop in discharge temperature or the reverse.

If evaporation of the solvent must be prevented, as would be the case when an organic solvent is used or in such work as the production of ammonium nitrate, previously referred to, the machine can be provided with a tight cover and all necessity for elaborate vapor-absorbing or air-conditioning equipment will be eliminated. If required, crystallization could occur under diminished or increased pressure.

The floor space required per ton of product is less than that for any other equipment described. This fact, together with a low initial investment and the small amount of liquor in process, reduces overhead charges to an unusually low figure and actual tests of various methods have shown this to be the cheapest of those tried.

Crystal size can be varied through a considerable range. This is primarily a factor of rate of cooling which may be varied by changing the



ANOTHER VIEW OF THE UNIT

*Patent applied for.



rate of feed and the water supply or by changing the concentration of the feed. With a more concentrated feed there will be a smaller amount of liquor to cool per ton of product, and consequently the cooling period may be longer and the crystals will be larger. When the desired size of crystal has been secured, it is necessary only to maintain the same conditions to continue the production of this grade indefinitely. The crystals have a tendency to be short and firm, so that they stand handling with a minimum formation of fines or dust.

The construction of the machine from standard sections permits it to be assembled in a variety of ways so that it can be adapted to almost any space available and can be enlarged or re-arranged at any time. When only a small tonnage is to be produced, one or more sections can be operated as a batch machine which will turn out crystals at a low cost and with a minimum of labor.

The cost of water may be the main item of expense in the operation of this machine, but the exit water has been in no way contaminated and therefore may be applied in other ways after this use. Its temperature has been raised considerably above the initial temperature and hence it is of greater value for boiler feed, for washing filter cakes and for many other purposes throughout the fac-

tory. In many cases the exit water from one crystallizer may serve as a cooling medium for another machine handling another product. Where the water does not need to have a very low temperature, it can be cooled in a spray pond and re-used. If a low temperature is required and cold water is not available, refrigerated brine may be used. In this case the mother liquor, after separation of the crystals, may in turn serve as a cooling medium in a preliminary section or sections of the crystallizer which are used as a heat exchanger.

If the mother liquor is not very dark colored and is clear, the magma from the crystallizer may be fed direct to a centrifugal while it is running at a moderate speed followed by a few minutes' whirling at high speed, to complete the removal of the liquor, and a slight washing with cold water and discharge by means of an automatic unloader. This arrangement when applied to the production of glauber's salt has given a large production with a minimum of labor. The use of an automatic or continuous centrifugal would give still lower costs.

When the mother liquor has a high color or has not been perfectly filtered, it is necessary to separate the bulk of it from the crystals, before feeding them to the centrifugal, by a dewaterer, which may be

operated as a separate unit or direct-connected to the crystallizer. This method has given a satisfactory product and has eliminated a very difficult and expensive filtration.

If the liquor contains sodium sulphate, there is a double gain, elimination of salting in the evaporator and the removal of 9 lb. of water for every 7 lb. of anhydrous sodium sulphate. Similar results are secured in crystallizing other compounds which form hydrates, and concentration is obtained at slight expense in comparison with the cost of evaporating the water and precipitating the anhydrous salt.

Even when a compound is not very soluble and does not crystallize in a hydrated form, it may be more economical to separate it by crystallization than by evaporation. Calculation indicates that this would be true for potassium sulphate, although it evidently would not apply in the case of sodium chloride.

Thus one more step in chemical manufacturing has been removed from the field of intermittent operation, with its attendant high costs, to that of continuous operation, with a greater uniformity of production in both quantity and quality, at a lower expense, and we have come one step nearer the ideal plant which will have chemists and operators, but no common laborers.

Vacuum Pan Evaporation in the Sugar Industry

A Discussion of the Most Perfect Crystallization Technique in Any of the Chemical Engineering Industries

BY CARL F. HUTTLINGER

Assistant General Superintendent, American Sugar Refinery Co.

THE sugar industry in its various phases presents a striking example of the well-known chemical engineering process of purification by crystallization. In the manufacture of raw sugar from the sugar cane, again in the manufacture of either raw or refined sugar from the sugar beet, and finally in the manufacture of refined sugar from raw sugar, whether the latter is derived from the cane or the beet, resort is had to this process. In the three phases of the sugar industry an impure solution of sugar, obtained by expression of sugar cane, by diffusion of sugar beets or finally by solution of raw sugar in water, is first partly

purified by treatment with heat and chemicals, by decantation, and (or) by filtration through cloth. In the sugar-refining industry a further partial purification and decolorization by filtration of clarified solution through bonechar is practiced. Then the sugar in the solutions is crystallized in vacuum pans, the relatively pure crystals are separated from the impure sirup or molasses by centrifugal machines, the sugars are dried and packed and the sirups again evaporated to recover additional amounts of sugar crystals.

The recovery of sugar crystals by evaporation of solvent through heating in open kettles with direct fire

has been practiced since the seventh century of the Christian era. This caused considerable inversion and caramelization and resulted in low yields of sugar and inferior sirups. Early in the nineteenth century the vacuum pan, embodying heating by live steam, was invented by Howard, an Englishman, who in 1812 and 1813 took out patents for

"(a) The suppression of the open-fired battery, met with everywhere in refineries, and the replacement of the many scattered fires by one central fire—i.e., under the boiler.

"(b) A device to boil the juices into *masse-cuite* at a low temperature to the benefit of the color and yield of sugar. This was to be attained by making use of vacuum, which was produced either by air-pumps or some other device." (See Koppeschaar, "Evaporation in the Cane and the Beet Sugar Factory.")

The vacuum pan of Howard consisted of a shallow steam-jacketed base surmounted by a dome. Base and dome were constructed of cop-



per. Steam at 15 to 30 lb. gage was introduced into the jacket and the vapors were withdrawn by a wet air pump. The temperature of the boiling juice was about 140 deg. F. Even the proof-stick was developed by Howard to permit drawing a sample of the contents of the pan. The capacity of the pan was small, say several hundred pounds.

The change from the open kettle heated by direct flame to the steam-heated vacuum pan created by Howard was revolutionary and epoch making. The development of the vacuum pan in the last hundred years has brought no radical departure from the fundamental principles of which Howard availed himself to his own great pecuniary gain.

In a later article the details of design will be discussed in relation to operating practice.

DETAILS OF OPERATION

The process of boiling sugar has in the past been surrounded with much mystery originating in the person of the sugar boiler, who thereby created for himself a peculiarly exalted and quite remunerative position. This attitude has not been tolerated for years. There is nothing particularly difficult and certainly nothing arduous about sugar boiling. The operation must, however, be carefully watched. Roughly, the process is as follows: The clean pan with foot-valve and vacuum breaker closed is partly exhausted either by air pump or condensing water or both and the amount of sugar solution required for grain formation is drawn into the pan through the charging line. Steam is then turned into the lower coils of the pan and the solution is raised to the boiling point, which, depending upon the vacuum and the concentration, may be from 110 to 150 deg. F. It is desirable to concentrate the sugar solutions under high vacuum, as greater temperature differences then exist between steam and solution and so more rapid boiling results. The solution becomes first saturated, then slightly supersaturated, and finally minute crystals form. In refined sugar manufacture it is exceedingly important that perfectly clear liquors are concentrated lest microscopic suspended impurities form nuclei for sugar crystals and, not being removable by subsequent washing in the centrifugals, produce a dull, off-colored product. The formation of minute crystals is called "graining," and

this operation is particularly carefully watched by the sugar boiler, who draws samples from within his pan by the proof-stick. When enough minute seed crystals have been formed and after the pan has been boiled fully and its contents concentrated to the desired point, the boiler prevents the formation of more crystals by reducing the supersaturation. This he effects by reducing the vacuum, which increases the temperature within the pan and by drawing in more sugar solution for concentration. The boiling proceeds by constantly drawing more sugar solution into the pan, evaporating the water therefrom, and causing the sugar to deposit on the minute seed grains first formed. As

It is a remarkable thing that the equipment and technique for the crystallization of sugar should have been developed over a hundred years ago. Still more remarkable is it that these should remain substantially unchanged throughout all these years and be still regarded as a high spot in chemical engineering technique.

more and more material is taken into the pan, the level of the boiling mass gradually rises, making it possible to turn steam into additional coils. To prevent burning of sugar, it is essential, of course, that, once steam is turned on a coil, the coil remain immersed in the boiling mass until the completion of the "strike" or charge. Care must be exercised that the crystals be not redissolved as a result of excessive drinks of sugar solution and that the concentration within the pan be not allowed to become so great that circulation be impeded and that "false grain" or further minute crystals form. When the pan is full the contents are concentrated to a water content of about 9 per cent and consist of a stiff mixture of about 60 to 65 per cent sugar crystals practically 100 per cent pure and 40 to 35 per cent of a saturated sugar solution containing the impurities. Steam is turned off of the coils, the vacuum released, and by opening the foot valve the mass within the pan is discharged therefrom into a mixer that feeds the centrifugals. These separate the pure sugar crystals from the impure mother liquor, which is returned to the pan for reboiling.

In the refinery the highest purity washed raw sugar solution after clarification and decolorization is boiled into a granulated sugar and a sirup, containing, after centrifuging, the impurities of the raw sugar in more concentrated form. The sirups are boiled back for granulated sugar about three times, by which time due to the removal of successive crops of granulated sugar the mother liquor or sirup is so impure and colored that it is no longer fit for white sugar production, even though 75 per cent of the solids therein are sucrose.

It will be of interest to quote one or two facts that will give a conception of the size of the vacuum pan used in the sugar industry. A large pan, say 17 ft. in diameter, will discharge about 2,500 cu.ft. of *massecuite* yielding about 300 bbl. of sugar every 1½ hours. At the beginning of the cycle, while the concentration within the pan is low, water is evaporated at the rate of about 60,000 lb. per hour, equivalent to approximately 2,000 boiler horsepower. Injection water will be required in the ratio of 15 parts per part of vapor condensed, or, say, 140,000 gal. per strike.

There is a tremendous loss in heat in operating a vacuum pan, as is evident from the fact that roughly 1 lb. of steam is required for each pound of water evaporated and as is evident from the fact that the only direct return of heat to the factory from this steam is the sensible heat of the condensate. To such extent as hot water may be required in sugar factories and refineries and may not be available from other steps in the process there can be recovery of heat from the vapors of sugar solutions by the installation of jet condensers if water suitable for the manufacturing or refining process is used in the condenser. However, this scheme will never permit of the recovery of more than a small fraction of the heat lost down the condenser, due to the limited fresh water requirement. Conservation of heat by utilization of vapor from boiling solutions for heating or for sweet water evaporation has been studied and attempted, and recently studies are being made of the recompression of low-tension vapor preparatory to its return for re-use as so ably described by Prof. W. L. Badger in this journal only recently. (See *Chem. & Met.*, vol. 28, Nos. 1 and 2, Jan. 3 and 10, 1923.)



Absorption

TILL recent years the separation of gases from gases by means of absorption had been developed as an art by experience and rule of thumb; but now modern technology is constantly filling in this gap between theory and practice. Both the theorist and the practical man are contributing to this progress. There was a time when the engineer designing and building his absorption tower was content to disregard theoretical considerations, covering up his ignorance by lavish overconstruction. Today sound engineering practice dictates saner methods. Large-scale experimentation with its costly changes is giving way to apparatus scientifically designed for efficient and economical operation.

A word here about our present treatment of this important subject: *Chem. & Met.* has just reason to be proud of the contributions it has already made to the

scanty literature on the theory of absorption, which is so well and briefly reviewed by Professor Baker in the first article in this section. Here, too, the reader will also find an ingenious attempt to classify the many and varied applications of gas absorption in the chemical engineering industries. Following this review both phases of absorption—i.e., design and operation, are treated in other articles.

Construction of absorption towers is a science in itself and there is, therefore, much of interest in the detailed design of any successful installation. With this thought in mind we are presenting a description of the huge granite towers used by the Norwegian nitrogen industry; and along somewhat the same line is the discussion of types of tower fillings, together with their limiting effect on scrubbing efficiency, which will be found in the concluding article of the series.

Basic Principles Underlying Gas Absorption

Their Practical Application in Solving the Wide Range of Industrial Problems Faced by the Chemical Engineer

BY E. M. BAKER

Department of Chemical Engineering, University of Michigan, Ann Arbor, Mich.

GAS absorption is one of the types of unit operations falling in the general classification of "counter-current extraction," just as do such other unit processes as distillation, drying, and the extraction of solids by liquids. The close correlation between these processes was presented by W. K. Lewis (*Ind. Eng. Chem.*, 1918, pp. 825-35). All of these extraction processes are concerned with the transfer of matter between two phases which are brought into more or less intimate contact, and generally in counter-current flow, either continuously or intermittently. Transfer of matter from one phase to the other will occur if there is a difference in the concentration potential of this matter in the two phases. Theory which has been presented deals with the maximum concentration change which might take place if the two phases were brought into equilibrium, and with the rate at which matter is transferred between the phases.

WHERE THE PROCESS IS APPLIED

In view of the basic similarity between gas absorption, as it is commonly known, and the related and overlapping processes of counter-

current extraction, it is difficult to list separately the applications of gas absorption in the chemical engineering industries. For those cases where the capillary theory¹ of adsorption applies, many applications of gas adsorption may also correctly be considered cases of gas absorption in so far as the basic theory is concerned, even though the adsorbed gas is not distributed evenly throughout the adsorbing (or absorbing) medium. Clearly the absorption of chlorine in hydrated lime to produce bleaching powder is an application of gas absorption, though the field, I believe, is generally regarded as restricted to the absorption of a gas, from a gas phase of at least two components, into a liquid. Even if restricted to this type of operation, the field of application is large, and specific applications may be conveniently classified according to the purpose of the operation into three groups, as follows:

(a) Gas absorption to recover a valuable gas, either as a marketable product or for re-use.

(b) Gas absorption to promote a chemical change, where the waste product contains the absorbed gas and the marketable product is the result of the reaction.

(c) Gas absorption to prevent nuisance.

Under group *a* it is desirable to include also the negative operation—viz., the evolution of a gas from a liquid into a gas phase having a lower concentration potential of the absorbed gas. A typical and common example of this is the Glover tower of the sulphuric acid works. The Gay-Lussac tower is an instance in which the gas is absorbed for re-use. Other examples of type *a* applications are found in the absorption of HCl gas to produce muriatic acid, absorption of NH₃ gas to produce aqua ammonia, the production of casinghead gasoline by absorption methods, the purification of artificial gas in gas works practice, the recovery of volatile solvents in various absorption oils, and even the recovery of volatile solvents by scrubbing with the refrigerated liquid solvent, though the last may also be regarded as merely indirect refrigeration of the gas phase.

A typical example of the type *b* application is the absorption of chlorine gas in a bromide-carrying brine, the waste product of the immediate operation being a chloride, and the market product (recovered by simple condensation or by a subsequent type *a* operation) being

¹McGavack, J., Jr., and Patrick, W. A., *J. Am. Chem. Soc.*, vol. 42 (1920), pp. 946-78, and also Miller, E. B., *Chem. & Met.*, vol. 23 (1920), pp. 1155-58, 1219-22, 1251-4.



bromine. It is true that there are cases lying between the type *a* and type *b* operations, such as the manufacture of chlorobenzene by direct chlorination of benzene. Half of the chlorine, if absorption is complete, goes out as the gaseous "byproduct" HCl, and half as the liquid "direct product" C_6H_5Cl .

In the type *c* application an obnoxious gas, that is not sufficiently valuable to justify recovery on these grounds, is absorbed to avoid creating a nuisance. The resultant product may be discarded as waste, or may possess a re-use value, in which event the operation may in time prove to be a type *a* application.

ATTACKING THE ABSORPTION PROBLEM

The classification of the unit process of gas absorption into these type *a*, *b* and *c* classes is most useful in illustrating the extent of the field, but is of little help in analyzing the specific problem. For this purpose the writer has suggested that most absorption problems may be subdivided into three minor divisions, based on the chemical nature of the gas-liquid system (see *Chem. & Met.*, vol. 22, pp. 122-4):

(1) A chemical reaction takes place, such that the gas will not exert an appreciable vapor pressure after absorption.

(2) A chemical reaction takes place, but the compound formed is sufficiently unstable so that the dissolved gas exerts an appreciable vapor pressure.

(3) No chemical reaction takes place, and the liquid exerts a vapor pressure of the gas dependent only on the concentration of the dissolved gas in the liquid phase.

An example of case 1 is the absorption of ammonia vapor in sulphuric acid. Since the resultant product, ammonium sulphate, exerts no vapor pressure of ammonia, it is theoretically possible to recover the ammonia completely by bringing the gas and liquid into intimate contact in a batch apparatus. The analysis of gas in absorption pipettes is dependent on this type of reaction, for it is a necessary condition that at equilibrium the pressure of the gas in the gas phase will equal the vapor pressure of the gas from the liquid phase. Thus this pressure of the gas from the liquid phase must be zero if complete absorption of the gas is to be obtained. It is only occasionally that such simple cases arise in practice.

Applications falling in class 2 are the most difficult to analyze, as in addition to all the factors involved in the absorption of the gas in the liquid to produce solutions of various concentrations, there are superimposed factors depending on the rate of reaction in the liquid phase. The complicated case of absorption of oxides of nitrogen in water in the presence of air to produce nitric acid has been well handled by J. R. Partington and L. H. Parker (*J. Soc. Chem. Ind.*, vol. 38, pp. 75-80T) by the use of certain "over-all" factors.

Applications falling in case 3, especially if the system is of such a nature that the solubility of the gas follows the Henry law, are the easi-

A better understanding of the fundamental principles reviewed in this article is bound to be reflected in better plant design and construction. There are still some remaining gaps in the theory of gas absorption and a number of debatable issues that must be studied critically and correlated with existing knowledge. Progress is being made, however, and more and more experimental data are becoming available for the chemical engineer who is willing to throw aside rule-of-thumb methods and design his absorption equipment scientifically.

est to handle, and have received the most attention from the standpoint of theoretical treatment.

W. B. VanArsdel in a paper before the American Institute of Chemical Engineers in 1922 reviewed the developments in the theoretical treatment of gas absorption and presented a theory free from many of the restrictive simplifying assumptions which characterized earlier papers. (See also *Chem. & Met.*, 1923, vol. 28, pp. 889-92). This review presents developments to the date of VanArsdel's paper clearly and briefly, and for that reason the following paragraphs are quoted directly from it.

"The basic principles of the process (gas-absorption) were laid down by Hurter¹ more than 30 years ago, but their application continued for many years to be qualitative rather than quantitative, partly, it is true,

because of lack of experimental data, but undoubtedly also because of the apparent complexity of the events in the apparatus and doubt as to how any pertinent constants could be sorted out of the mass of variables. Lunge's comments² on Hurter's work are a good example of the way in which plant designers viewed gas absorption. An article by Heinz³, appearing only 8 years ago, was written from the same viewpoint; attention was directed almost exclusively to the design of the packing material, and the only other suggestion that could be made was that 'experience shows' that 16 meters per minute is the best gas velocity in a tower.

Since about 1919 the growth of interest in unit processes has been reflected in the appearance of much more work on absorption towers. In that year Zeisberg⁴ published his data on the resistance of various styles of tower packing to gas flow, and Partington and Parker⁵, in England, developed the theory of nitric acid absorption towers and calculated from experimental data many of the constants necessary for design. In the following year E. M. Baker⁶ illustrated certain principles of gaseous absorption by data on an ammonia scrubber, and Donnan and Masson⁷ established by theoretical analysis the basis of the old qualitative rules of good practice. In the interests of simplicity, however, they assumed that temperatures and gas volumes were constant throughout the system, thus limiting considerably the applicability of their results.

Since that time a number of papers have appeared on this and related subjects: Masson and McEwan⁸, for instance, assume equilibrium attained throughout a solvent-recovery tower and calculate the efficiency of the system by the summation of a series of finite steps; Thomas⁹, also postulating equilibrium conditions, found fair agreement

¹Lunge, "Sulphuric Acid and Alkali" (1909), pp. 312-30; 379 ff.

²R. Heinz, "Absorption and Reaction Towers for the Chemical Industry," *Z. angew. chem.*, vol. 26 (1913), pp. 419-21.

³F. C. Zeisberg, *Chem. & Met.*, vol. 21 (1919), pp. 765-7.

⁴J. R. Partington and L. H. Parker, *J. Soc. Chem. Ind.*, vol. 38 (1919), pp. 75-80T.

⁵E. M. Baker, "Absorption of Gases in Spray Systems and Towers," *Chem. & Met.*, vol. 22 (1920), pp. 122-4.

⁶F. C. Donnan and I. Masson, "Theory of Gas-Scrubbing Towers With Internal Packing," *J. Soc. Chem. Ind.*, vol. 39, pp. 236-41T.

⁷I. Masson and T. L. McEwan, "Recovery of Solvent Vapors From Air," *J. Soc. Chem. Ind.*, vol. 40 (1921), p. 32T.

⁸R. Thomas, "Recovery of Alcohol Vapor From Air," *J. Soc. Chem. Ind.*, vol. 41 (1922), p. 34T.

⁹Hurter, *J. Soc. Chem. Ind.*, vol. 4 (1885), p. 639; vol. 6 (1887), p. 707; vol. 8 (1889), p. 861; vol. 12 (1893), pp. 225, 417, 990.



with theory in the behavior of an alcohol-vapor recovery system; and W. K. Lewis, analyzing the processes of rectification" and distillation", suggests a line of attack for certain cases of temperature and volume change. Whitman and Keats" give experimental results on solute and heat transfer in a coke tower, a McLaurin scrubber and a spray chamber; in all cases the results are calculated by greatly simplified formulas. It must be said, however, that a very wide field of theory and experimentation remains to be explored before the design of absorption towers becomes as definite a matter as that of, say, steel structures."

SUBSEQUENT DEVELOPMENTS

Subsequently, two more theoretical articles have appeared. One by the writer which will appear in the *Trans. Amer. Institute Chem. Eng.* for June, 1923, shows the close relationship between gas absorption and distillation, and develops calculations, substantially free from simplifying assumptions, based on the summation of a series of finite steps. This article also presents an extensive bibliography. The other article, by W. G. Whitman [*Chem. & Met.*, vol. 29 (1923) pp. 146-8] presents a study of the rate of transfer of gas between the two phases, and advances a "two-film" theory of gas absorption, based on difference in pressure of the gas in the two phases which is taken as the concentration potential.

Numerous other articles have appeared from time to time, reporting properties of packing materials, performance of particular equipment, and also adding in some measure to the growing store of theoretical knowledge.

It is safe to say, however, that at this writing much remains to be done in the study of underlying theory, the digestion and correlation of existing theory, and the accumulation of test data on the performance of accurately described apparatus, operating under accurately described conditions.*

*W. K. Lewis, "Efficiency and Design of Rectifying Columns for Binary Mixtures," *J. Ind. Eng. Chem.*, vol. 14 (1922), p. 492.

W. K. Lewis, "Evaporation of a Liquid Into a Gas," *Mech. Eng.*, vol. 44, (1922), p. 445.

W. G. Whitman and J. L. Keats, "Rates of Absorption and Heat Transfer Between Gases and Liquids," *J. Ind. Eng. Chem.*, vol. 14 (1922), p. 186.

*An article presenting clearly such data on a hydrochloric acid system was read at the June, 1923, meeting of the American Institute of Chemical Engineers by J. R. Withrow.

How Norsk Hydro Absorbs Its Dilute Nitrous Gases

Huge Granite Absorption Towers Capable of Handling 25,000 to 30,000 Cu.Ft. of Gas Per Minute Are Described in Detail and Replacement Costs Estimated

BY T. C. HAGEMANN,
New York City

Formerly Chief, Mechanical Department, Norsk Hydro-Elektrisk Kvaelfabrik

ONE of the technical problems put before the engineers of Norsk Hydro-Elektrisk Kvaelfabrik (Norwegian Hydro-Electric Nitrogen Co., Ltd.), Christiania, in connection with the arc process for fixation of atmospheric nitrogen was the cooling, oxidation and absorption of large quantities of nitrous gases, leaving the Birkeland-Eyde furnaces at a temperature of about 1,000 deg. C., containing about 1.2 per cent NO and 98.8 per cent air. The cooling was carried out in steam boilers and aluminum coolers, and the oxidation in empty towers of sheet iron, lined with bricks, which supplied the absorption system with a gas containing about 1.8 per cent NO, and 98.2 per cent air at a temperature of 50 deg. C.

The absorption problem was solved by using series of large granite towers filled with broken quartz.

HOW THE TOWERS WERE MADE

These towers have a decagonal section and are built up of granite slabs, 6½ ft. wide, 3½ ft. high and varying in thickness from 12½ in. in the lower rows to 7½ in. in the upper rows. The cross-section area of each tower was 333 sq.ft., the height 66 ft. and the capacity 22,000 cu.ft.

The granite slabs in each row are held together by steel rods running over cast-iron blocks at the corners and tightened by turnbuckles at the middle of each stone. The stones are set with a layer of asbestos and water glass. All joints are calked outside and inside with fibrous asbestos saturated with water glass.

The filling material consists of broken quartz varying in sizes from 2 in. at the bottom to ¾ in. at the top. The packing rests on a grill of granite, supported by larger granite stones, this disposition allowing an even flow of gas over the whole section. The upper 3 ft. of the tower space is also left without quartz, thus making the net height of quartz filling about 55 ft., volume 19,300 cu.ft.

The construction of the granite absorption towers demands the most

scrupulous care as to material and workmanship. The granite and quartz used was all submitted to a test for acid resistance. The 20 years' experience of Norsk Hydro has resulted in towers which have been in active service year after year, practically without a leakage. The gas pipes between the towers are made of acid-proof stoneware with bell-and-spigot ends. The gas is drawn through the system by a fan placed behind the alkaline tower following the last granite tower. The gas leaving the alkaline tower is practically neutral, thus permitting the use of iron fans. It was found that the best type of piping for acid conduits is stoneware pipes with conical flanges, held together by steel bolts and cast-iron braces. The circulation of the absorbing liquid is effected by montejus of acid-proof stoneware, having a capacity of 130 gal. The elevators have no moving parts inside, and working in a single stage the acid pressure rises to about 3.5 atmospheres. It is safe to say that the construction of this apparatus represents one of the most difficult tasks which up to that time had ever been put before the stoneware manufacturer.

OPERATING RESULTS

The large factories at Rjukan and Notodden, mostly operating with the Birkeland-Eyde furnaces, are divided in units of about 10,000 kw., each unit receiving about 675,000 cu.ft. of gas per hour. By arranging four towers as mentioned in series and working with counter-current, 82 per cent of the NO₂ content of the gas will be obtained at the bottom of the first tower in the form of nitric acid containing 30 per cent HNO₃. An additional 15 per cent is absorbed in caustic soda as sodium nitrite in an iron tower, placed behind the fourth granite tower, the remaining 3 per cent being lost with the escaping gases.

The arc process has been developed on a very large scale in Norway, 200,000 kw. now being utilized at



Rjukan, of which 70,000 kw. is used in the Schoenherr furnaces and 130,000 kw. in the Birkeland-Eyde furnaces. In addition 40,000 kw. is being utilized in Birkeland-Eyde furnaces at Notodden, representing a total power consumption of more than 2 billion kilowatt-hours yearly.

The chief product is the very valuable fertilizer, Norwegian saltpeter or calcium nitrate, produced by mixing weak nitric acid with limestone. During the war most of the acid produced was neutralized with ammonia to form ammonium nitrate.

Some authors—with more or less knowledge of the matter in question—have charged the absorption system adopted by Norsk Hydro with being of a lavish character. The fact

remains, however, that the whole system works absolutely automatically and requires a minimum of attendance and repair.

It is of course impossible to make an accurate calculation of replacement costs in America, at least without knowing the location of the plant in contemplation. The following, however, is based upon pre-war conditions in Norway with allowance for American post-war conditions and must be considered as roughly approximate. The prices of granite and quartz, for instance, depend almost entirely on the freight—viz., the distance between the quarries and the plant.

Approximate cost of construction of absorption system of an arc

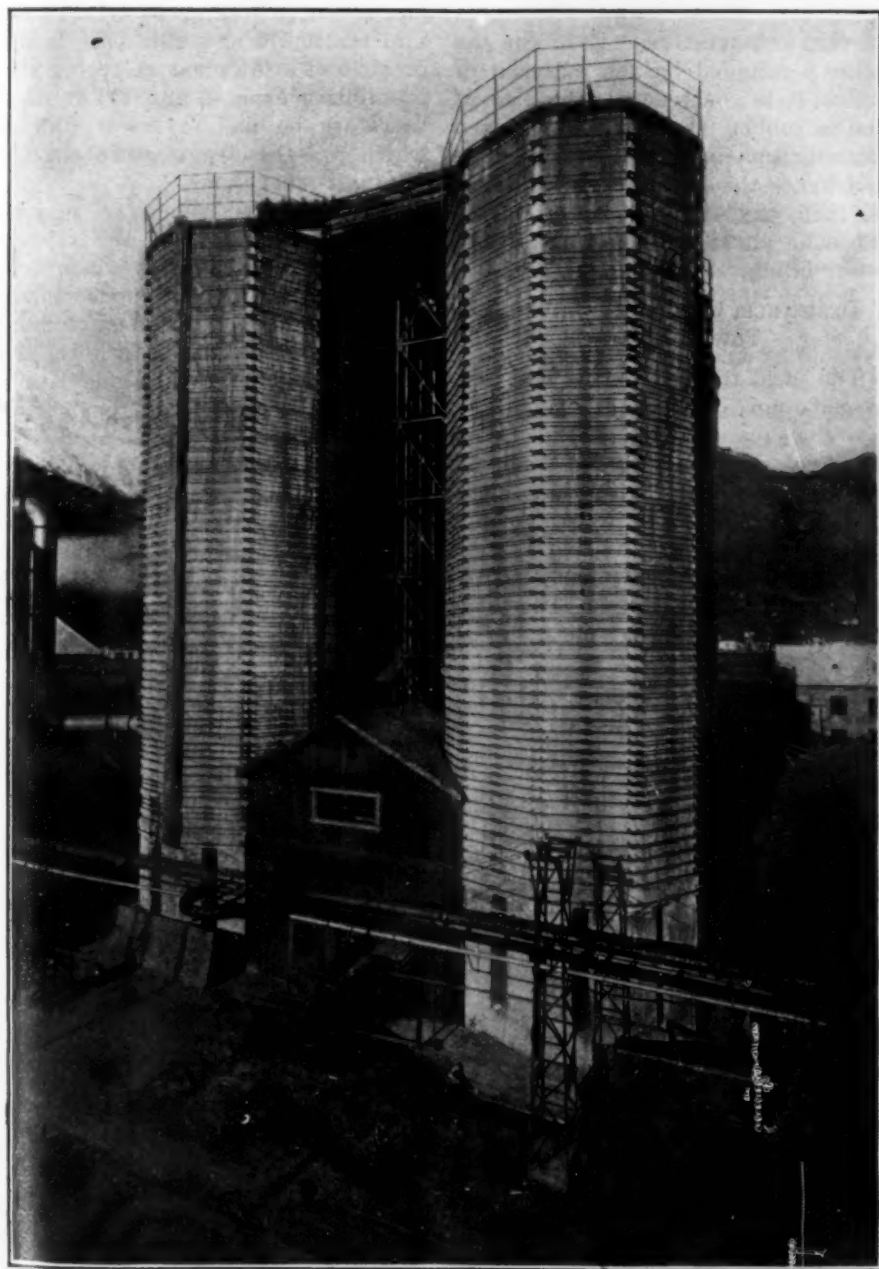


FIG. 1—ACID ABSORPTION TOWERS OF NORSK HYDRO AT SOULOM, HAUTES-PYRÉNÉES, FRANCE

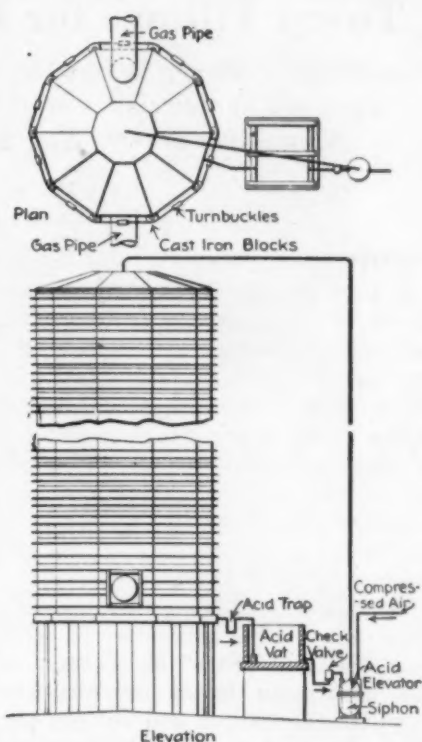


FIG. 2—PLAN AND ELEVATION OF GRANITE ABSORPTION TOWERS

process plant, power consumption 10,000 kw., four towers in series, is as follows:

Four granite towers filled with quartz, including foundations...	\$100,000
Gas pipes from oxidation chamber to alkaline towers.....	5,000
Blower	5,000
Acid elevators and acid conduits..	15,000
Air compressors and air piping..	5,000
Total	\$130,000

It has proved to be unnecessary to inclose the towers in houses. Accordingly, at the most recent factory, at Soulom, Hautes-Pyrénées, France, constructed during the war, the towers have been placed in the open air, as shown in the accompanying picture. The acid elevators and piping at the foot of the towers are sheltered. Similar disposition has been made at the extension of the Notodden factories, Norway, where the temperature during the winter drops to 20 deg. C. below zero.

Granite is extensively used for other purposes in arc process plants—for instance, as building material for smaller towers for absorption of strong nitrous gases coming from the sodium nitrite-nitrate inversion plant and for acid-concentrating towers. Furthermore, it is used in storage tanks and neutralization towers for production of calcium nitrate. Where the right kind of granite is obtainable, it has the advantages of being cheap, strong and acid proof. It is also possible to make the joints between the individual stones absolutely acid proof.



Tower Fillings for Industrial Absorption

Scrubbing Efficiency Is Shown to Depend Among Other Factors on Certain Characteristics of the Filling Elements, and in This Connection Several New and Old Types Are Compared

BY PAUL D. V. MANNING,
Chemical Engineer, New York City

THE most effective way of absorbing soluble gases and vapors from large quantities of gas is by scrubbing or washing the gas with a suitable absorbing liquid. This may be accomplished in several different ways, as by passing the gas over or against a wetted surface, by spraying the liquid through the gas, by a combination of the two processes or by bubbling the gas through the absorbent.

The apparatus in most common use consummates the absorption by passing the gas from the bottom of an absorption tower or scrubber, through the column and out the top, the absorbent or washing liquid meanwhile descending countercurrently from the top to the bottom of the tower. The tower itself, as is the case with a fractionating column, must be provided with a means of bringing the gas and liquid into intimate contact, and for this purpose may contain a filling or be fitted with a series of plates with bubbling caps or both. The scrubber is very similar to the fractionating column and in many respects the two operations are analogous. Both have as their object the bringing about of an equilibrium between a gaseous and a liquid phase.

The operation of absorption by scrubbing depends upon the following factors (see E. M. Baker, *Chem. & Met.*, 1919, vol. 21, pp. 765-7):

1. There is, under given conditions of temperature, pressure and partial pressure of solute in the gaseous phase, a maximum concentration of the solute in the absorbent. This is reached as a limit when the partial pressure of the solute in the liquid equals the partial pressure of the solute in the gaseous phase. In perfect countercurrent scrubbing this would be reached at the absorbent outlet of the apparatus.

2. What Whitman (*Chem. & Met.*, 1923, vol. 29, pp. 146-8) terms the "driving potential," which is dependent on the difference between the partial pressures of the solute in the gas and in the liquid.

3. The intimacy of contact between the two phases.

4. The duration of the contact interval.

The first two factors can be influenced, under equal conditions of temperature and pressure, only by a careful selection of the absorbent used. The third and fourth, however, depend directly upon the type of construction and tower filling used. Considering the construction of the tower itself, it is evident that this also is dependent upon the filling used, for, if the filling presents a surface comparatively small for the volume occupied by the material of which it is constructed, the size of the scrubber shell for any given capacity and time factor will be large and hence the cost will be high. It is, then, easy to realize the importance of a careful selection of the tower filling.

DESIRABLE CHARACTERISTICS OF TOWER FILLING

The ideal tower filling is one that is made up of elements which (1) give the greatest amount of useful or effective surface for the smallest volume; (2) do not introduce more than a small resistance to the gas flow; (3) make the fluid film as thin as possible, and (4) give good distribution without channeling. The ratio of the actual volume of the material

of which the filling is constructed to the volume filled should be as small as possible and the effective area per unit volume filled should be as large as possible. In this connection the term "porosity" is often used and is best defined as the ratio of the volume of free space to the volume of filled space.

Ideal action dictates that the gas passing through the scrubber be continually changing its surface film, the gas streams broken up and their motion such as to give the greatest possible mixing, presenting thereby to the liquid film a gas film which is as thin and therefore as concentrated in solute as is possible. The liquid likewise should flow in as thin a film as possible and at such a rate that it will reach equilibrium with the gas film almost instantaneously. To obtain the liquid as a film only is impossible of attainment excepting at a prohibitive expense and resort must therefore be had to tower fillings, which give the largest useful surface per unit of volume.

Useful or effective surface may be defined as that part of the surface of a filling over or about which both fluid films are in continuous motion and contact. Thus the effect of channels and stagnations is to lower the effective surface. In the one case, a large part of one fluid (considering both the gas and liquids as fluids) passes through the channel with little turbulent motion of mixing, thus rendering that part of the surface ineffective through lack of contact and the other parts ineffective through stagnation. In the case of stagnation, part of the filling is rendered ineffec-

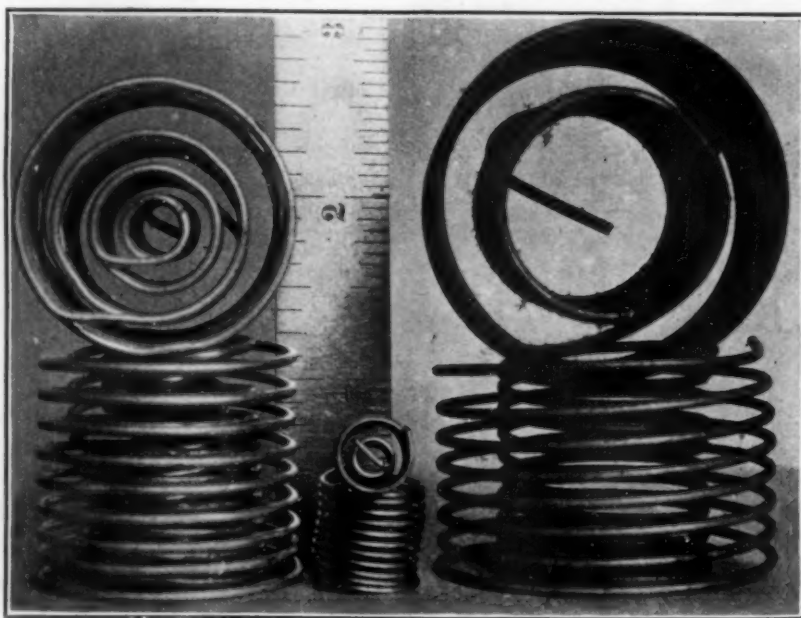


FIG. 1—A NEW TYPE OF TOWER FILLING. SHOWING LABORATORY AND INDUSTRIAL SIZES



tive through a lack of motion of the fluids, a "dead spot" being the result. It is for this reason that fillings such as steel wool or coke, having many small pores, do not present a large active surface, although the actual surface is large.

The absorption being influenced by the amount of effective surface through the area of the film and by the time factor, which in turn is governed by the thickness of the film, in addition to the previously considered vapor pressure relations, it is apparent that the filling which gives the larger effective surface with a complementary tower arrangement insuring a well-distributed liquid film will give the greatest efficiency. If also the filling elements can be thrown into the shell at random without danger of channels or stagnations, the saving in first cost will be great.

SOME NEW AND OLD TYPES OF FILLING

The most common type of tower filling in use today consists of sets of wooden grids or slats, commonly known as "hurdles." Such a filling is fairly cheap and is easily constructed and installed. Its resistance to the gas flow is low and it is not easily clogged by dirt and deposits from the absorbent. Its effective surface per unit volume is, however, comparatively low and the free space left to the gas is small as compared with the space occupied by the wood itself. Its use involves, therefore, the construction of large scrubber shells wherever a large surface of contact, together with a long time of contact and a high porosity, is desired. It is light in weight and gives a uniform porosity. This type of filling is treated from a practical standpoint by Dykema in Bureau of Mines Bulletin 176. Its use is not advisable, of course, in cases where the absorbent or gas would injure the wood and cause a short life of the filling.

The best form for tower filling elements would seem to be that of a cylinder, the diameter of which is equal to the height (see A. Hutin, *Rev. Prod. Chim.* 1918, vol. 21, pp. 169-70). The usual dimension is about 1 in., or 2.5 cm., in Europe. Several types of fillings which meet these conditions will be briefly described. Most of them are already well known and are largely used for scrubber filling as well as for filling fractionating columns.

The spiral ring packing is used largely for towers handling acid

solutions and gases and consists of an earthenware cylinder having a spiral baffle through the center. It is a larger element than the ones later described, but presents a large effective surface. It must be placed in the tower carefully.

The Raschig ring type of filling is a simple cylinder such as would be formed by cutting a pipe into short pieces. It is thrown into the tower at random. It may be made of practically any material.

The Lessing ring is an element the shape of which would result from the bending of a piece of sheet metal into a cylinder, beginning the bend about $\frac{1}{4}$ in. from one end. It thus has the surface of a Raschig ring plus that of the unbent end which extends through the center of the cylinder.

The Prym ring is a modified Lessing ring, the inside unbent edge being bent into the shape of a small letter *e*. Its surface is large. Like the Lessing, it is made only of metal.

MULTIPLE WIRE HELIX

A new type of filling element that has found use in Europe recently is the Bregat multiple helix. This element consists of two, three or four wire helices coiled coaxially. The four helix type is most commonly used. It is shown in Fig. 1 together with a larger two helix type and several smaller types for laboratory column use. This filling presents an effective surface for volumes occupied larger than that of any other element and this is further increased in use through the formation of films

of liquid between the turns of wire. These films are constantly broken and re-formed and the gas stream is greatly divided. The elements are thrown into the tower at random in layers of several elements deep, the latter being separated by open spaces to allow redistribution and gas mixing.

CONCLUSION

In conclusion, the following points should be emphasized in the design and construction of scrubbers: The selection of the best absorbent; the selection of the filling suitable to withstand the action of the gas and liquid; the selection of the filling which gives the largest ratio between the free volume around the filling and the volume filled, at the same time giving the largest ratio between the effective wetted surface and the volume filled; the providing of cleaning and inspecting doors of ample size at various heights in the scrubber shell; the providing of manholes at the top and bottom; the method of placing the filling in the tower; the means of distribution of the liquid at the top of the scrubber with inspection glasses on each line at this point; the filling should be put in in layers, the tower not solidly filled, and around the shell at these points should be an angle iron which causes the liquid running down the sides of the tower to be redistributed to the filling; provision for steaming with large quantities of steam for cleaning should be made and catch pots and traps should be provided on the gas lines to stop the loss by entrainment of the liquid in the gas.

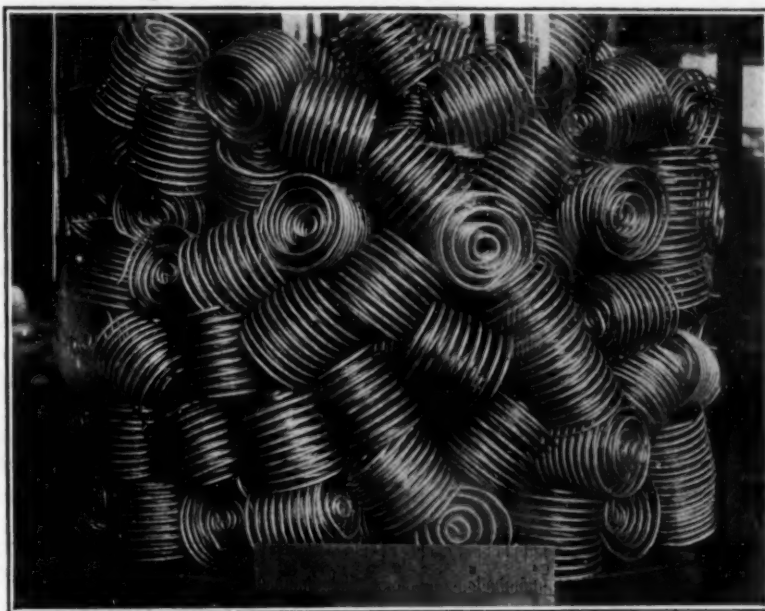


FIG. 2—ASSEMBLED IN A GLASS CYLINDER TO SHOW METHOD OF PACKING



Refrigeration

THE manufacture and utilization of cold is becoming of ever-increasing importance to chemical and allied industry. Among its important applications are the production of such gases as oxygen and hydrogen, the production of cold storage for various commodities used in manufacturing processes, the conditioning of air for industrial plants and the enriching of air for metallurgical process work. The fundamental importance of these and other uses makes it worth while to review this subject in its elementary

aspects and to develop the fundamental principles.

With this idea in mind we present the accompanying paper. The author of this paper explains the methods by which refrigeration can be obtained commercially, and compares the various refrigerants available and the types of equipment manufactured for their application. This is done in such a clear and simple manner that it should prove of great service in keeping the important facts about refrigeration before those who are responsible for the industries in which it is used.

Refrigeration: What It Is and How to Use It*

The Theory Upon Which the Available Systems of Natural and Mechanical Refrigeration Operate, With Charts and Tables Which Will Aid in the Solution of Refrigerating Problems

BY SEYMOUR A. WOOLNER

Norwalk Iron Works, South Norwalk, Conn.

REFRIGERATION is any method suitable use of steam or electric power. In using these forms of energy some working medium—or refrigerant—must be employed, such as ammonia, sulphur dioxide, ether, ethyl chloride, carbon dioxide or methyl chloride. The refrigeration is obtained by means of the physical law that heat must be supplied in order to vaporize any liquid, and that in the process of boiling the liquid cools the source of the heat because it abstracts heat from it. But why go to all this trouble if there is plenty of ice and salt available?

It is perfectly true that practically everything now done by means of refrigerating machines was performed in earlier days by means of natural ice. Even ice for household and commercial purposes was cut a

few years ago in the nearby pond or river, or perhaps shipped in from places farther north. But these conditions have changed because of the increased contamination of the water supply, the increased cost of cutting and transportation, and dirt, and because of both the space required in the use and storing of the natural ice and the varying quantity of natural ice in different winter seasons. It is clearly proved that water subject to pollution is positively dangerous if used as a supply for natural ice, where the ice is allowed to come into contact with food either directly or indirectly. For this reason the boards of health in many places have taken drastic measures to guard against the use of natural ice or ice made from polluted water supply.

INTRODUCING MECHANICAL COOLING

The result of the objections to the use of natural ice was that in 1855 the ammonia absorption machine was invented by Carré, and the Perkins ether machine was commercialized both in the United States and in Australia. One compression machine was erected in Cleveland,

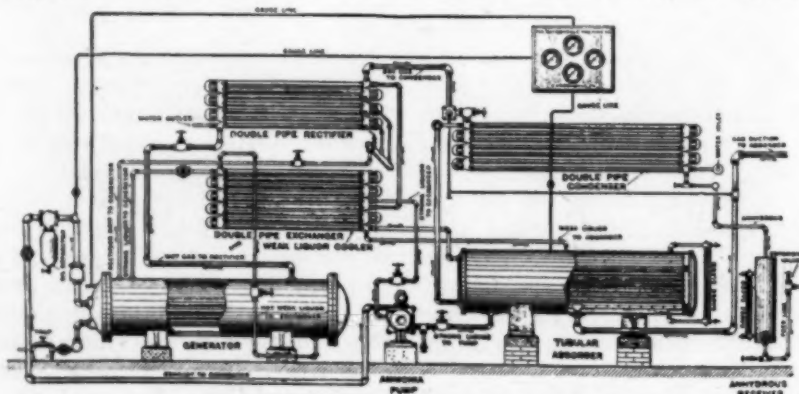


FIG. 1—AMMONIA ABSORPTION SYSTEM

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Ohio, which had a capacity of 1,600 lb. of ice daily and was in use at various times for about 3 years. Improvements and additional designs followed quickly. In 1855 the sulphur dioxide machine was developed by Pictet, and then the carbon dioxide machine was invented by Windhausen. The ammonia compression machines were built by a number of companies. These refrigerating machines, similar to the modern designs, were built to work on the closed cycle—that is, taking the vapor boiled from the liquid refrigerant in the cooling coils and compressing it to a point where (by bringing the compressed, hot gas into metal contact with ordinary cooling water) it would be liquefied and made ready for a second and continued use in the refrigerating coils. The refrigerating machine makes possible continuity of performance, a ready control of the capacity, a perfect control of the refrigerating temperature, and (by means of suitable piping) a neat and convenient means of conveying the refrigeration to the points requiring cooling, all in an ideal hygienic manner.

A box refrigerated by the use of a cold brine or direct expansion coil has none of the troubles incidental to the use of ice. The air is dry, the temperature is that desired by the owner and refrigeration is not variable, as is the case of the ice bunker.

DATA ON REFRIGERANTS

Before proceeding with a more detailed description of the value of a refrigerant it is necessary to make a choice of a suitable refrigerant. This has been a process of elimination, and has been governed by the improvement of the machines and apparatus used in the industry. The refrigerants that are really in good use today (and, in fact, almost exclusively used) are ammonia, carbon dioxide, sulphur dioxide, ethyl chloride and methyl chloride. Accompanying will be found a table giving absolute pressure of these mediums at 0 deg. F. and 95 deg. F.

In Table I it will be seen that ammonia has a much greater heat of evaporation and a reasonably low working pressure. Within the last few years the carbon dioxide machine as a refrigerant has gained rapidly but there are many industries and many locations where mechanical refrigeration is desirable where the

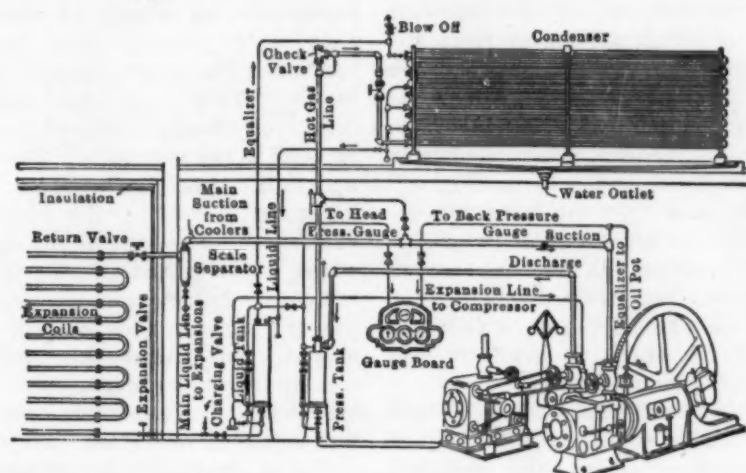


FIG. 2—COMPRESSION SIDE OF A COMPRESSION REFRIGERATING SYSTEM

use of ammonia is a potential hazard due to its flammability and asphyxiating nature.

The Absorption System

The ammonia absorption system is based upon the great solubility of ammonia gas, which, at ordinary temperatures, is about 700 volumes of the gas to one volume of water. The apparatus required consists of the generator, the rectifier, the exchanger, the condenser, the liquid receiver, the expansion coils and the absorber as shown in Fig. 1. Of course, minor apparatus is used, including the necessary pumps and pipe connections.

The expansion coils, condenser and liquid receiver used in this system perform identically the same functions as in the ammonia compression system, and have the same relation to one another. The ammonia absorber is a cylindrical drum, much like a horizontal tubular boiler, with interior tubes parallel to its longitudinal axis, terminating in tube sheets located near each end. Through these tubes is passed cooling water, which must cool the mixture of water and ammonia in the shell surrounding. A weak mixture of water and ammonia, termed weak liquor, continually flows into the absorber from the exchanger, which apparatus is described later. Ammonia gas that has already done its work in the expansion coils is led into the bottom of the absorber

through a perforated pipe, and bubbles up through the liquid contained therein.

This "weak liquor" immediately absorbs the gas and, thus strengthened, becomes known as "strong liquor." The ammonia pump takes this "strong liquor" from the absorber, pumping it through the exchanger, referred to above. This ammonia pump is the only moving piece of apparatus required in the ammonia absorption system. The exchanger is usually built on the double pipe principle, and, as its name indicates, is used for the exchange of heat. It might also be called a "weak liquor" cooler, for the cold "strong liquor" which has just left the absorber while being pumped through the pipes takes up some of the heat from the hot "weak liquor" on the same pipe going back through the generator to the absorber. In this way the "strong liquor" is warmed to some extent and then passes on to the generator.

The generator is a cylindrical drum in which is suspended a set of steam coils. Low-pressure steam

TABLE I

	Absolute Pressure at 0 Deg. F. per Sq. In.	Absolute Pressure at 95 Deg. F. per Sq. In.	Latent Heat of Evaporation at 0 Deg. F.
Ammonia.....	29.95	197.30	572.2
Carbon dioxide	314.00	1,211.00	124.4
Sulphur dioxide	9.93	77.64	172.0
Ethyl chloride	4.04	31.80	190.4
Methyl chloride	18.73	110.10	176.0

TABLE II

	Total Heat at 80 Deg. F.	Heat of Liquid	Difference Columns 1 and 2	Specific Volume at 0 Deg. F.	200 Specific Volume Col. 3	Column with CO ₂ as Unity
Ethyl chloride.....	177.0	20.5	156.5	18.8	24.0	30.2
Carbon dioxide.....	99.8	28.9	70.9	0.282	0.795	1
Sulphur dioxide.....	161.9	16.1	145.8	7.49	10.28	12.95
Ammonia.....	611.6	132.0	479.6	9.11	3.80	4.78

For 70 deg. condensing water (80 deg. condensation) and 0 deg. boiling temperature.



from the exhaust of the ammonia pump, if steam driven, or from any other source, is made to pass through these coils and in this manner the "strong liquor" inside the generator is heated. A steam pressure of from 10 to 20 lb. is sufficient, and it will thus be seen that the ammonia absorption system is mostly a by-product system to be used when there is excess steam for which no other use can be found, a constant amount of which is available 365 days in the year.

Should conditions arise which would make necessary the use of high-pressure steam, the economy of the plant is immediately destroyed. In addition, the design of the plant is such that it is not intended for the use of high-pressure steam. The generator is not usually built for high pressure. In this generator the greater part of the ammonia in the "strong liquor" and some of its water are vaporized by the steam, forming a hot wet gas, which flows away from the generator, leaving a hot "weak liquor" behind. The ammonia gas driven out of the liquor produces a pressure head within the generator; and, driven by this pressure, the stream of "hot liquor" flows through the exchanger, then through the "weak liquor" cooler (which is only another set of double pipe coils, cooled by running water), from which point the "weak liquor" flows back to the absorber as first described, completing that cycle of operation.

Returning to the hot wet gas escaping from the generator, this is led to the rectifier, which is a series of pipe coils arranged with a drip

connection on several of the pipes. Cold water passing from the coils condenses the water vapor in the ammonia. This condensed water is drawn off through several drips and returns to the generator. The warm ammonia gas, now free from moisture, passes to the condensers and from there to the liquid receiver, where it is stored in the form of anhydrous liquid ammonia, ready for use in the expansion system as required. Afterward this same gas coming from the expansion coils is led back to the absorber, completing that cycle of operation.

Fig. 1 illustrates the ammonia absorption system and is typical of the many plants of this type that have been installed by the Carbondale Machine Co., of Carbondale, Pa., and Henry Vogt & Co., of Louisville, Ky.

To summarize, the advantages of this system are three:

Simplicity of control; the fact that exhaust steam can be utilized; and the fact that very low temperatures are possible.

The principal disadvantages are the absolute necessity for the use of steam in a commercial installation; low thermal efficiency of the process; and the fact that the system must be operated at a fairly constant rate and thus is not really flexible.

The Compression System

In the compression system, the compressor, which is nothing but a pump, draws in the refrigerant from the expansion coils, compressing it sufficiently so that cooling water at normal temperature may condense it. From this point the gas follows the same cycle. It must be condensed, the liquid stored, passed into the expansion coils and then returned to be recompressed. Fig. 2 illustrates a typical compression system regardless of the refrigerant used. It will be seen that it is a closed cycle throughout.

The function of the compressor being only to compress the gaseous refrigerant, it is the only place (in the simple refrigerating cycle) where power is supplied; and it is therefore to this point that one looks for the most economical design details. If the compressor is a pump and simply acts as a connecting link between the low-pressure side and the high-pressure side of the system, it must be so constructed as to do its work with the smallest amount of losses, usually caused by the valve action (the suction and the dis-

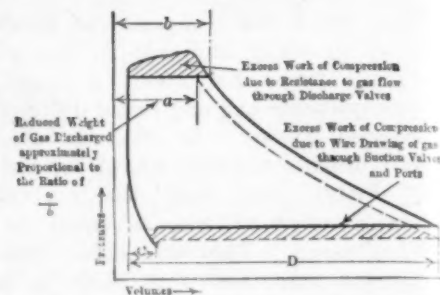


FIG. 4—INDICATOR DIAGRAM SHOWING APPARENT VOLUMETRIC EFFICIENCY

Distance piston travels before suction valve opens. Volumetric efficiency (apparent) = $\frac{D-C}{D}$.

Note—This is an indicator diagram, and the area (as, for example, the hatched area) is equal to the work done by the piston on the gas in the cylinder.

charge valve) and by the heating effect of the cylinder walls on the refrigerant.

The suction pressure is determined by the temperature desired in the cooling coils. The highest practical suction pressure should be carried, because in so doing the largest number of pounds of the refrigerant are pumped and it is always the weight of the ammonia or the carbon dioxide that is pumped and fed through the expansion valve which provides refrigeration. Friction losses resulting in a drop of pressure in the discharge valves and ports should be avoided, if possible. During compression, the vapor becomes hot, frequently 200 deg. F. or higher, depending on the initial temperature and the amount of compression required. In consequence, the compressor walls, the piston and valve ports become heated, the actual amount depending on the use of the cylinder.

Liquid injection (wet compression) was formerly used in order to reduce this temperature, which might be employed in performing useful refrigeration. We now consider wet refrigeration a bad practice except where excessive discharge temperatures are experienced, in which case only enough injection should be employed to reduce the discharge temperature to a reasonable amount.

Efficient lubrication and compressor design assist in cutting down the high temperature of the gas. The cylinder walls are, however, hotter than the suction gas and some bad effects are experienced in consequence. The gas entering the cylinder absorbs heat from the relatively hot walls and becomes

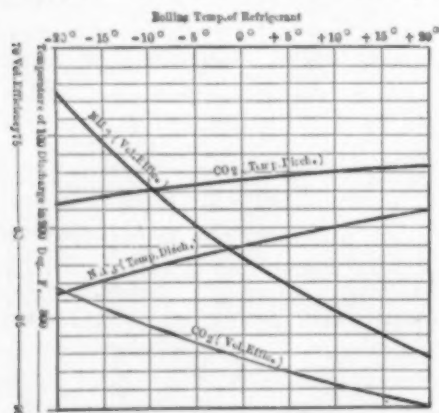


FIG. 3—EFFECT OF COMPRESSION ON DISCHARGE TEMPERATURE AND CLEARANCE ON VOLUMETRIC EFFICIENCY

Conditions: Condensing temperature of refrigerant, 85 deg. F. (about the condition with 70 deg. water). Dry and saturated vapor entering compressor.



superheated, thereby reducing the capacity of the machine because of the rise of temperature and therefore causing an increase in the volume per pound of the refrigerant. Mention is made here of this matter because certain refrigerants (ammonia, for example) have a greater pressure ratio and therefore a greater discharge temperature for the same suction than has carbon dioxide. Naturally, the effect of the discharge temperature on the real volumetric efficiency will not be so great for CO_2 as for ammonia. The same thing is also true of the apparent volumetric efficiency, which is a function of the pressure—i. e., ratio of the discharge to the suction pressure.

EFFECT OF CLEARANCE AND TEMPERATURE

The expanding gas in the clearance space returns most of the work of compression to the compressor and no real loss is occasioned by having from 4 to 8 per cent of clearance. However, the real effect of clearance is in the reduction of the capacity of the compressor, which (for a certain set of conditions) is in proportion to the piston displacement.

Fig. 3 shows the effect of compression on the discharge temperature and clearance on the volumetric efficiency for various suction and discharge pressures for carbon dioxide and ammonia. From this the advantage of carbon dioxide is apparent, because both of these effects may be seen in Fig. 3. For example, using 0 deg. F. boiling temperature of the refrigerant, the discharge temperature for carbon dioxide and ammonia (the diagram is for a head pressure corresponding to usual practice when using 70 deg. F. condensing water) is 148 and 219 deg. F. respectively, and the volumetric efficiency (with no clearance) is 87.2 and 81.6 per cent respectively. Note particularly, however, that the real volumetric efficiency must not be confused with re-expansion due to clearance and given by the apparent volumetric efficiency as shown in Fig. 4. This distinction is very important.

The real volumetric efficiency takes into account the effect of the heating of the suction gas due to coming into contact with the relatively hot cylinder walls, etc.

The carbonic machine shows a decided advantage here, first, because

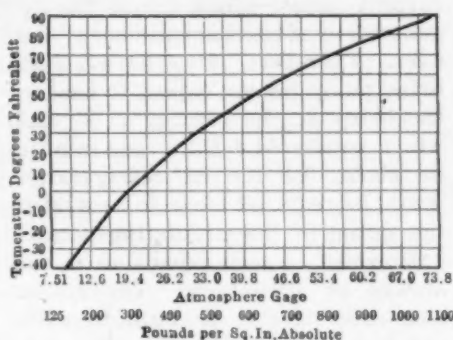


FIG. 5—PROPERTIES OF SATURATED CARBON DIOXIDE

of the fact that the discharge gas temperature is less than with ammonia under similar conditions, and therefore does not usually cause stuffing box or other trouble, even without liquid cooling or the water jacket; and second, because the weight of the gas pumped per cu.ft. of piston displacement is more nearly theroretically perfect—i. e., 87.6 per cent, as compared with 81.6 per cent.

COMPARISON OF REFRIGERANTS

As to the actual advantage of one refrigerant over all others, this is really a factor of the location of the machine and the work which is desired to be done. In the United States most stationary plants are ammonia. In Great Britain about half of the stationary plants are carbon dioxide. Practically all marine installations use carbon dioxide in their refrigeration machines and on the continent of Europe large sulphur-dioxide machines have been built, but at the present time sulphur dioxide, ethyl and methyl chloride have been relegated to the use of the household machine, where their relatively high latent heat of evaporation and relatively low working pressure makes their use very satisfactory.

Carbon dioxide requires the least piston displacement per ton of refrigeration of all known refrigerants; about $1/4.8$ of that required of ammonia and $1/13$ of that required of sulphur dioxide. In consequence, the carbon dioxide cylinder volume is relatively very small. In addition, carbon dioxide has no chemical action on any metals whatsoever, with the result that copper may be used in the condenser and the brine cooler, thereby allowing compact, self-contained piping, of a kind readily made tight by welding, and with much better heat transfer.

It has always been believed that

copper and ammonia may not be used on the same installation, but there are some instances where ammonia and copper have been used with remarkably good results. This, however, is still a matter of expediency. With sulphur dioxide copper may be used as long as there is no air in the system, but should air enter the system with its moisture sulphuric acid forms and the effect of this upon copper is known to all.

Ethyl chloride and methyl chloride may be used in the system with copper except where glycerine is used as a lubricant.

HOW REFRIGERATION IS APPLIED

In the application of refrigeration there are two general and main subdivisions. After the refrigerant has been condensed and is stored in liquid form, it is ready to do the useful work of refrigeration. It is then permitted to flow through expansion valves into what is known as the low side of the system. This low side may take one of two forms, either the direct expansion system or the brine system. One of these is used in every application of refrigeration in one form or another; and sometimes, because of the peculiarity of the work to be done, a combination of the two is used. These two systems, however, are the main subdivisions by which the useful work of refrigeration is done, and unless the low side is carefully planned and just as carefully executed, the best efforts of the best compressor or condenser will be in vain.

The direct expansion system for refrigeration means expanding the refrigerant in coils directly in the space to be cooled, as for instance in the bunker coils of a butcher box, in the bunker coils of an air compressor for an air-cooling system, or in the coil space of a low-temperature room of a cold storage warehouse. With ammonia it is best to use brine exclusively, because of the danger incidental with direct expansion inside the rooms to be refrigerated or with the pipe lines leading from such rooms frequently exposed to accidents of one sort or another. In addition there are fire department regulations in the larger cities throughout our country, which sometimes prohibit a direct expansion ammonia system. With carbon dioxide the danger element is nil and may be forgotten, but what must be considered is the absolute neces-



sity of making up the shells in the best possible manner and with the best workmanship, as any defective or poorly made joint will be a source of gas loss which in a carbon dioxide system is difficult to trace. It is usually possible to lay out the system so that there are no joints in inaccessible places. This may be done by using welded coil. Flanges are used with carbon dioxide, because it is comparatively simple to make a flanged joint tight.

The suction pressure must be kept as high as is practical—for example, if +10 degrees F. is required in refrigerating coils for direct expansion, it would be necessary to have zero degree boiling temperature of the refrigerant. The compressing pressure for carbon dioxide and ammonia can be readily found by referring to the curves in Figs. 5 and 6. With brine, the refrigerant (for the same conditions in the refrigerating coils) would have to boil at -10 deg. F., requiring a suction pressure corresponding to that temperature. It will be seen, therefore, that for the direct expansion system a higher back pressure can be carried and therefore less quantity of gas will be pumped per ton to do the same work. This means, on the part of the compressor alone, that it is necessary to add approximately 20 per cent to the size of the compressor in order that the brine system may be used. The horsepower per ton of actual refrigeration increases rapidly with the reduction of suction pressure and the brine system has to pay for the power required to circulate the brine. Brine circulation means friction and eddy

current losses, which means the degeneration of mechanical energy into heat. Therefore, if we have a 2-hp. brine pump we can expect to heat up the brine at the rate of 2×42.4 , which equals 84.8 B.t.u. per minute, or about 0.4 ton of refrigeration would be required alone to neutralize the action of the circulating pump.

However, direct expansion is not always an advantage. The expansion coils have to be built to withstand the operating pressures without many leaks. To prevent leaks means as little use of joints as possible, the employment of selected pipe, careful welding, etc. The amount of piping (actual surface) is about the same in amount as with brine, but very much more than in the case of the standard copper coil brine cooler for carbon dioxide. Small units, using short individual coils, with long runs between them, operate with difficulty under direct expansion. Under these circumstances it is far better to use the brine system. Furthermore, it is very difficult to control automatically a direct expansion system, for the reason that the thermostatic control can be placed in only one cooling tank or box.

Probably more serious still from the operating standpoint is the lack of storage capacity. Direct expansion means 100 per cent operation. The stoppage of the machine means almost immediate defrosting of the pipes with its resulting dripping, and this water must be cared for without harming the surroundings. For variable loads such as pasteurizing milk, ice cream making, cooling theaters and auditoriums or where

the load is intermittent, the machine under direct expansion must be large enough to carry the peak load. For such kinds of work the brine system with a storage tank would seem to be the best, unless it can be proved that the peaks are of long duration and that the overhead and other costs make direct expansion profitable.

USING THE BRINE SYSTEM

When brine is used, the refrigerant boils in the brine cooler or brine tank, which is usually located in the compressor room and makes (for the refrigerant) with the compressor and the condenser a very compact, self-contained plant. In other words, the refrigerant is confined to the compressor room and only brine, which may be pumped through a building under very low pressure, somewhat similar to a hot water heating system, leaves the compressor room.

The direct expansion system is said to be cheaper to operate. This is because there is no brine pump (as with the indirect system) to operate and because, with a higher suction pressure possible, the horsepower per ton of refrigeration is less and the capacity of the machine is attained. This statement is true for all refrigerants.

In the brine system there is a loss because it is an indirect system. The boiling refrigerant cools the brine, the brine cools the air or the other substances, and there must in consequence be a double "temperature difference" in this case over that using direct expansion. For instance, if a cold storage room is to be held at 35 deg. F. we should calculate our piping for a certain temperature difference between the outside and the inside of the pipe. Suppose we take this as 10 deg. F.; then, taking carbon dioxide as an example, a suction pressure of 455 lb. absolute (41 atmospheres) would be required for direct expansion. But if brine were used, the suction pressure would correspond to 15 deg. F., or 389 lb. absolute (26½ atmospheres). In consequence of the lower suction pressure the tonnage would decrease to about 84 per cent, and the horsepower per ton would increase about 9 per cent. In addition a brine pump has to be used continuously which (just from the churning effect, resistance to the flow in the pipes, etc.) will heat the brine to about one-fifth of a ton of refrigeration per horsepower of the brine pump. These are

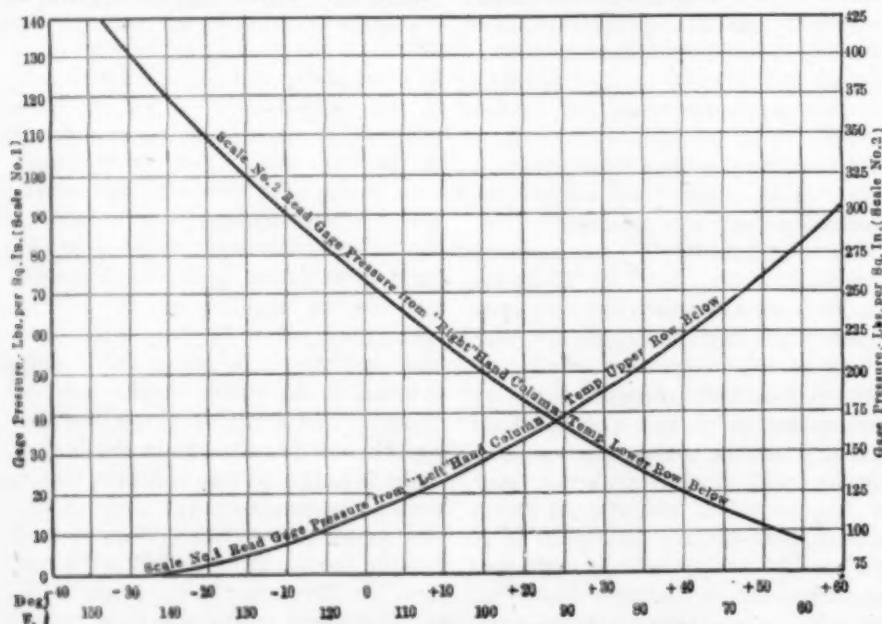


FIG. 6—PROPERTIES OF SATURATED AMMONIA GAS



TABLE III—TABLE FOR CALCIUM CHLORIDE BRINE

Lb. per Gal. Water	Deg. Salometer at 60° F.	Deg. Bé. at 60° F.	Sp.Gr. at 60° F.	Sp.Ht.	Freezing Point Deg. F.	Ammonia Gage Suction	Wt. per Gal.	Per Cent	Wt. per Cu.Ft.
2.5	80	20	1.159	0.844	4	18	9.666	18	72.322
3	88	22	1.179	0.834	—2	12.5	9.833	20	73.570
3.5	96	24	1.199	0.817	—9	8	10.000	22	74.818
4	104	26	1.219	0.799	—17	4	10.166	24	76.066
4.5	112	28	1.240	0.778	—27	1 in. vac.	10.342	26	77.376
5	120	30	1.260	0.757	—39	8.5 in.	10.517	28	78.686
5.5	...	32	1.283	0.735	—54	15 in.	10.700	30	80.059

TABLE IV—TABLE FOR SODIUM CHLORIDE BRINE

Lb. per Gal. Water	Deg. Salometer at 60° F.	Sp.Gr. at 60° F.	Sp.Ht.	Freezing Point Deg. F.	Ammonia Gage Suction	Wt. per Gal.	Per Cent	Wt. per Cu.Ft.
0.433	20	1.037	0.960	25	38	8.65	5	64.71
0.895	40	1.073	0.892	19	32	8.95	10	66.95
1.395	60	1.115	0.855	12	26	9.30	15	69.58
1.920	80	1.150	0.829	6	20	9.60	20	71.76
2.485	100	1.191	0.783	1	16	9.94	25	74.32

all very serious matters, and must be considered carefully.

The brine system seems to be the most ideal system, first, because all the refrigerant is confined to the compressor room, and second, because the most accurate control of temperature is possible by this method. An important factor is that of the storage ability of brine. Refrigeration may be stored up in the brine. In the case of periodic loads, it is an advantage to be able to do so. For this a brine tank of suitable dimensions is used and during the period of light load the brine temperature is brought down and the "refrigerating capacity" of the brine (at the depressed temperature) is utilized to carry the peak load when that develops. With brine, the plant is very self-contained, and under the eye of the engineer or the operator. There are no long suction lines and the liability of leaks, etc., is made an absolute minimum. The cold end is under hydrostatic pressure only and need not be constructed of materials stronger than that required for liquids under nominal pressures.

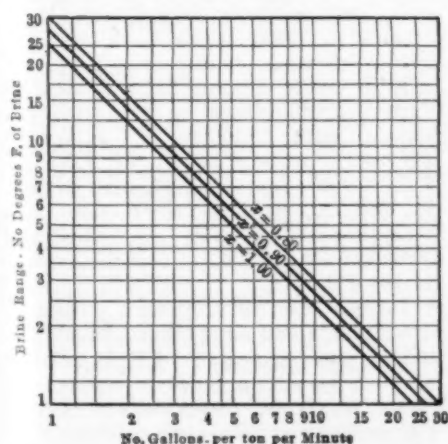


FIG. 7—CHART FOR DETERMINING GALLONS OF BRINE REQUIRED FOR 1 TON OF REFRIGERATION AT VARIOUS TEMPERATURE RANGES

Corrosion in the refrigerating system has been very carefully studied, but there are so many factors influencing the subject that one is not positive of one's premises. Corrosion may be due to "stray electric power," to galvanic cell action due to dissimilar metals in the line, or even a difference in the manufacture of two sets of steel or iron pipe. No commercial brine is chemically pure, and therefore each contains more or less of the other. As a rule it can be said that if the brine solution has a strength of 1.14 specific gravity, is free from the presence of carbon dioxide in solution and is slightly alkaline no corrosion will occur with either kind of brine.

The refrigerating engineer must look out for the concentration to be carried, as well as the specific heat. First he should decide on the lowest temperature required by the plant for satisfactory operation, and then he should select a concentration which has a freezing temperature for that particular kind of brine sufficiently lower to be on the safe side. (See Tables III and IV.) The idea, of course, is that we concentrate the solution to a point where it will carry the desired temperature without danger of freezing. The freezing of the brine is one of the most serious conditions possible, as far as carrying the load is concerned, that is likely to be met with. Then comes the matter of the "specific heat" of the brine or its "specific heat capacity." The heat capacity of water is almost without exception the greatest of any solid or other liquid and is taken as unity. As the concentration of the brine increases its unit weight increases, but the specific heat decreases in greater proportion, so that the product of the specific weight and the specific heat is less than unity. Referring to

Tables III and IV, it will be seen that the specific heat may be as low as 0.7 (for calcium brine). Some of these facts can be brought out nicely in an example: Suppose 100 gal. of brine per minute of 1.2 specific gravity (its weight is 1.2 times as great as water) is cooled 4 deg. F. If its specific heat is taken as 0.7, find the tonnage developed:

One gallon of brine will weigh $8.33 \times 1.2 = 10$ lb. Then 10 (weight per gal.) $\times 100$ (number of gallons) $\times 0.7$ (specific heat) $\times 4$ (temperature drop) = 2,800 B.t.u. = 14 tons. Or suppose it was required to find out the number of gallons required per ton per minute for a 5 deg. range: Then 5 (range) $\times [7.2 \times 8.33 \text{ (weight per gal.)}] \times 0.7$ (specific heat) \times gallons = 200 or the gallons per minute =

$$200$$

$$5 \times 1.2 \times 8.33 \times 0.7 = 5.72$$

Fig. 7 will give this in detail for certain ranges of concentrations and specific heats, using the product of the two factors specific heat and specific gravity (density) as one of the variables, given as x on the diagram, as given in the tables.

USING RADIATOR SECTIONS IN PLACE OF PIPE COILS

As it is true that the cast-iron radiator has practically supplanted the pipe coil in steam heating, so it is likely that the cast-iron section will replace the steel or wrought-iron pipe for brine. There are a number of reasons for this. In fact, it can be said that cast iron is less corrosive than steel or wrought iron. The reason for this is probably because of the "skin" caused by chilling during casting and because of the lack of "mill scale" or other causes of local galvanic action.

The section is easily erected. It comes in standard sections, of 7 ft. refrigerating surface, which are easily connected together. The required surface is obtained by having enough sections. Cutting of pipe, except for feeder lines, is nearly entirely done away with.

The main objection in the use of brine, as already mentioned, is the cost of pumping and the resulting heating factor due to the heat equivalent of the work done in pumping. Instead of a long coil of 100 to 400 ft., we have the parallel flow through the sections. This resistance to flow is from one-half to one-quarter what would be found in an equal area of pipe.



Industry and Trade

Current News and Market Developments

Chemical Exposition announces that prizes will be given this year for exhibits of unusual merit.

New cement mills in South strengthen industry in Alabama.

Priestley medal to be awarded to Remsen.

Japan's disaster not likely to affect the chemical oil prices to higher levels.

industries of this country seriously.

Summary of the Week

Canadian oleomargarine act is now in operation.

Tariff Commission resumes hearings under flexible provisions of tariff law.

Producers of methanol announce decline in price schedule.

Active demand forces crude cottonseed

Stocks of gasoline showed marked decline during July.

Foreign Trade in Chemicals Increased in July

FOREIGN trade in chemicals and allied products in July expanded 48 per cent for exports, rising from \$9,852,531 in July, 1922, to \$14,566,066 in July, 1923, and 5 per cent for imports, from \$14,449,237 to \$15,106,824. The largest gains occurred in coal-tar chemicals, which more than doubled for exports, from a total valuation of \$898,638 in July, 1922, to \$1,922,987 in July, 1923, and imports 70 per cent, from \$809,638 to \$1,381,063. Total exports of coal-tar chemicals in July surpassed total imports by more than half a million dollars. The total trade in both crudes and intermediates was greater in July, 1923, than in July, 1922, while for finished coal-tar products the exports were nearly double the value of the imports, which fell 10 per cent below the July, 1922, figure. During July, 1923, foreign shipments of colors, dyes and stains amounted to 2,915,531 lb., worth \$778,169, while receipts equaled 160,940 lb., worth \$236,777. Medicinals to the value of \$8,450 (23,568 lb.) were sent abroad, while \$12,602 (1,856 lb.) worth entered the United States.

Fertilizer Exports Double

Fertilizers and fertilizer materials, exports of which more than doubled, from 57,765 tons, with a value of \$1,072,198, in July, 1922, to 119,423 tons, with a value of \$2,550,860, in July, 1923, dropped in imports from 183,270 tons, valued at \$4,601,625, to 116,741 tons, valued at \$4,053,879. In July of this year, 17,751 tons, valued at \$1,456,488, of sulphate of ammonia was shipped abroad, while no receipts were recorded. Foreign shipments of phosphate materials, superphosphates and prepared mixtures were considerably in excess of those for July, 1922. Lesser amounts of calcium cyanamide, crude chloride of potash, sulphate of potash, kainite and manure salts were received in July, 1923, than in July,

1922. On the other hand, larger amounts of sodium nitrate came in during July of this year.

The paint, pigment and varnish group recorded an increase of 96 per cent over July, 1922, in exports, but a decrease of 21 per cent for imports. The aggregate value of \$254,125 for the total imports was but 15 per cent of the total exports. Although the imports, amounting to 8,511,135 lb., worth \$93,170, of mineral earth pigments exceeded the exports, amounting to 2,449,862 lb., worth \$75,328, those of chemical pigments were but one-seventh the exports, which equaled 6,201,400 lb., valued at \$851,769. One noticeable feature of the foreign sales of this group was the comparatively small shipments of lithopone (136,050 lb., valued at \$8,607) which were made in July, 1923. Exports of paints, stains and enamels in July, 1923, were valued at \$546,167, while the imports were valued at but \$31,151.

When compared with the foreign purchases of 10,866,997 lb., valued at \$1,098,622, of linseed oil, the sales of 244,961 lb., worth \$37,615, are relatively unimportant. Receipts of china wood oil amounted to 1,236,450 gal., with a value of \$1,236,450, in July, 1923.

Naval stores, gums and resins, another important group both as to exports and imports, although the commodities included under the groups differ considerably in character, expanded 56 per cent for outward and 24 per cent for inward trade, rising from an aggregate value of \$1,845,649 in July, 1922, to \$2,878,194 in July, 1923, for the former, and from \$1,981,366 to \$2,461,000 for the latter.

Foreign sales of rosin in July, 1923, amounted to 110,945 bbl., valued at \$991,025; of spirits of turpentine to 1,718,099 gal., valued at \$1,703,122, and of wood turpentine to 72,660 gal., valued at \$74,699. Receipts of varnish

gums in July, 1923, were 7,028,002 lb., valued at 1,816,235, of which amount 2,175,202 lb., valued at \$1,220,958, was shellac.

Gains in Sodium Compounds

Foreign trade in sodas and sodium compounds showed gains in July, 1923, over July, 1922, both in outward and inward movements, although a comparison of the inward trade is not available. The aggregate value of the total exports of sodas and sodium compounds improved from a total of \$769,419 (29,781,688 lb.) in July, 1922, to \$923,411 (40,750,452 lb.) in July, 1923. Not only did the sales of sodium cyanide represent an important expansion but also the purchases, which were likewise double the sales, showed gains. Increase in foreign demand for American borax, soda ash and caustic soda were evident in July, 1923.

Exports of all acids and anhydrides diminished in July, 1923, acetic acid having fallen to less than 5 per cent, sulphuric acid to 65 per cent and boric to 67 per cent of the July, 1922, figure. Figures for the imports of acids for July, 1922, are not available, but indications are that gains were made in 1923. Of the acids imported, arsenious acid or white arsenic, with a total of 1,212,354 lb., valued at \$111,631; sulphuric, with 1,515,400 lb., valued at \$10,646; oxalic, with 172,925 lb., \$12,892; and tartaric acid, with 280,000 lb., \$66,520, were the chief ones. The total imports of acids and anhydrides were valued at \$226,313 and the exports at \$66,059.

During July, 1923, foreign shipments of ammonia and ammonium compounds, baking powder, acetate of lime, calcium carbide, bleaching powder, copper sulphate, dextrine, formaldehyde, potash bichromate and potassium chlorate were all considerably below the July, 1922, figures. Although foreign shipments of glycerin were greater this year than last, receipts were only one-quarter of the sales. No citrate of lime was received during July, 1923.



Silk Worst Hit of Japanese Industries

Much of Season's Crop May Be Lost—Industries of Interior, Arsenic, Graphite, Oil Reported Unharmed—Effect of Disaster on Trade Difficult to Evaluate

JAPAN today faces a supreme tragedy. The exact extent of her losses cannot be stated. It is certain that the greatest silk port of the world, Yokohama, lies in ruins. How much raw silk was in storage there is unknown. How vitally the Nagoya district, from which our best silk comes, is affected is also uncertain. The opinion of many merchants familiar with the topography of the island is that this district was entirely devastated. The Hochiyaji district, also an important producing area, apparently suffered heavily. The Matsumoto area probably escaped damage. Preliminary estimates would indicate that from 35,000 to 40,000 bales of silk at Yokohama were destroyed, that this loss combined with that of the rich cocoon raising areas may bring the total losses of raw silk to approximately one-half of that amount which we would normally import during the present season.

Chemical Plants Destroyed

While definite information is still lacking, it is believed by Washington experts in Far Eastern affairs that the chemical industry of Japan suffered heavy loss. In the suburbs of Tokyo, or between the capital and Yokohama, its port, are located several of the largest chemical manufacturers in Japan. Among the most important of these are the Kanto Sanso at Oji; Sankyo Co., Ltd.; Hoshi & Co.; S. Suzuki & Co., and the Japan Acetic Acid Works. These companies produce sodas, acids, quinine and chlorate of potash principally.

Japan has been exporting considerable quantities of arsenic and graphite. Both of these industries are located in the interior. So far as is known only small stocks of these chemicals were in store in the ports destroyed. As a result the only derangement of these industries to be expected will be that due to interrupted transportation facilities.

It is said that cargoes of inbound caustic and ammonium sulphate are probably lost. As far as the ammonium sulphate is concerned at least, this probably will have little importance because it is known that in trading on the New York market recently Japanese merchants have made the lowest quotations on this commodity. This is thought to indicate overbuying during the spring season.

Kobe Chief Chemical Port

Kobe rather than Yokohama is the chief port for the handling of chemicals. Through this port, which is west of Yokohama, our large purchases of oil have come in the past despite the fact that the industry is located to the north and east of the devastated area.

It is in the vicinity of Kobe that the principal textile and dyestuff mills were located, and as a result little disruption of these industries is looked for. Osaka, the greatest industrial city of Japan, is unharmed. It is in the vicinity of these two cities, the former being the port of the latter, that Japan's copper and galvanizing industries are located. To the west again are the steel works, particularly the great government works at Moji and Nagasaki.

Our trade in chemicals with Japan this year found its peak in the months of May and June. Since that time, it has continued to fall off in volume. One

A Friend in Distress

It is too easy at a time like this to regard the tragedy of our Japanese friends across the sea merely from the viewpoint of its possible effect in setting up action and reactions in industries here at home. Such an attitude can be justified only if our primary consideration is for a people in distress, to do all within our power to alleviate their misery, to prove to them simply and directly that we are more concerned in their comfort and well being than in their industries and marts of trade.

of the largest firms dealing in Japanese chemical imports stated that it expected no trouble in filling its present orders. Due to the demoralized condition of the railroad system, however, delays in getting materials from the east of Japan to the west are inevitable. In the case of silk, delays are likely to result from loss of warehouses necessary for government inspection.

Already there are indications here of a live demand for steel to be used in repairing the devastation. Apparently American steel makers are disposed to give preference to Japanese orders above all others. Feverish buying of steel plate is reported in London. There can be little doubt that Japan intends to rebuild wherever possible with a minimum of delay. Inasmuch as this country has been one of our leading buyers for some time past, this fact is considered significant.

Net Effect Not Clear

What the total effect of the earthquake on our chemical and allied industries will be can obviously not be predicted with any accuracy. With silk high and scarce, mounting rapidly in price, stimulation of our fiber silk industry may result. If the silk industry should become slack as a result of depletion of raw material, such weighting salts as tin crystals may be in less demand. Such considerations are at

this time mainly in the nature of conjecture.

A delay of 8 weeks is considered inevitable in receiving shipments now on order, according to J. A. Goldsmith, president of the Silk Association of America. If delays are longer than this, he believes that recourse to fiber silk for fabrication will be made by American mills. His view of the situation is optimistic, and is based on a trip to the Orient just completed. He says:

"The United States need not worry about its supply of silks. There will be enough. If the devastated area is no larger than at present indicated, the effects of the destruction of the Yokohama stocks will soon be over. In the meantime we must think of the Japanese. That was the attitude at the meeting of the Silk Association yesterday and that will continue to be the attitude of every respectable manufacturer in the United States until the trouble is over."

The loss of chemicals in transit and storage is too slight to react decidedly in any way. Kobe, being not only the port through which most of our commerce, excluding silk, entered and departed but also the port through which the main part of Japan's shipping to the Far East was handled, is standing and functioning. The great disaster centers on the silk shipping and raising areas and ports. Silk and steel, it seems, may be affected decidedly, but not in such a way as to react adversely here.

Linseed Production in Canada Runs High

The prairie provinces of Canada during the past 5 years produced 5,730,000 bu. of flaxseed per year, a large proportion of which is used in the making of linseed oil. A report of production of this oil for 1920 shows that there are eight mills in Canada crushing flaxseed, of which Manitoba has two, Alberta one, Ontario two, Quebec three. There was used 1,527,096 bu. of seed, from which there was produced 2,627,265 gal. of linseed, oil, 798,975 gal. of boiled linseed oil, and miscellaneous products, including oil cake and meal, to the value of \$2,149,903. The capital invested in the industry was \$2,911,634, and the number of employees 214. Last year imports amounted to but 1,173,454 lb., whereas in 1921 there was 5,955,926 lb. imported.

Industrial Notes

The Seiberling Rubber Co., manufacturer of automobile tires, has closed down its plant at New Castle, Pa., for an indefinite period, effective Aug. 31, and will concentrate operations at its mill at Akron, Ohio, where it is expected to develop maximum production with a full working force.

The Alabama Power Co. will soon commence the manufacture of calcium arsenate in its plant at Montgomery, Ala., using an electrolytic process.



Washington News

Imports of Coal-Tar Dyes Decline in August

Imports of coal-tar dyes at New York during August totaled 178,164 lb., with an invoice value of \$194,164, according to statistics compiled by the Chemical Division of the Bureau of Foreign and Domestic Commerce in collaboration with the Chemical Section of the Tariff Commission.

Previous imports during 1923 were:

Month	Lb.	Value
January*	179,309	\$185,344
February	191,709	199,690
March	312,809	301,436
April	242,022	256,761
May	261,869	292,340
June	247,174	257,803
July	144,687	142,428

*Not complete.

The five dyes leading in quantity imported in August were: Indanthrene blue 3G; Gallamine blue, Indanthrene green B; Alizarin synthetic; and Rhodamine 6G. Of the total quantity imported in August, 1923, 52 per cent came from Germany, 35 per cent from Switzerland, 11 per cent from Italy and 2 per cent from other countries. Of the total quantity imported in July, 46 per cent came from Switzerland, 43 per cent from Germany, 9 per cent from Italy, 1 per cent from England, and 1 per cent from other countries.

Importations of color lakes during August aggregated 4,057 lb., with an invoice value of \$2,881. Imports of synthetic aromatic chemicals in August totaled 5,180 lb., with an invoice value of \$11,402. Imports of medicinals, photographic developers and other coal-tar chemicals totaled 17,226 lb., with an invoice value of \$24,404.

Logwood Extract From Haiti Indicates Growing Industry

Production and shipment of logwood extract by a plant at Grande Riviere, Haiti, for the first six months of 1923 has totaled 544 tons, valued at \$41,799, according to a report to the Chemical Division of the Bureau of Foreign and Domestic Commerce by American Consul Damon C. Wood, at Cape Haitien. This production is a substantial gain over the 417 tons, valued at \$17,561, manufactured by this plant in the corresponding period of 1922.

Logwood sticks ordinarily form the principal Haitian product shipped from the Cape Haitien consular district to the United States. No shipments, however, were made in either May or June of this year, compared with 2,632 tons, valued at \$40,593, in the same months of 1922. In May and June a cargo of 1,278 tons of logwood sticks, valued at \$19,807, was shipped to the United States from the neighboring port of Fort Liberté. The Cape Haitien price of the untrimmed wood has varied recently from \$6.40 to \$9.20 per metric

ton, the Bahun wood commanding the latter price. These figures mark a substantial advance over the price of \$5.65 per ton which was paid a year ago. Thinning of the logwood forests, with increasing difficulties of transportation, have been mainly responsible for the rise in price.

Maximum Values Sought in Sale of Seized Dyes

While agents of the Department of Commerce are observing the disposition of the dyestuffs and chemicals seized by the French and Belgians in the Ruhr for the information of the trade in the United States, the State Department has made no representations to the governments concerned regarding the sales plan. The State Department was requested by the Synthetic Organic Chemical Manufacturers Association to make official representations against any action that would tend toward dumping on the American market. There has been no official information regarding the progress of sales of 3,800 metric tons of dyestuffs which were to be disposed of for export, since the sales started Aug. 20. Both the French and Belgian Governments, however, have expressed to the companies representing them in the sales a desire to obtain maximum prices and put the dyes on the market in such manner as will not disturb world trade.

Cresol Disinfectants Favored in South China

According to reports from our consuls at Hongkong and Canton there is a fair demand for disinfectants in Hongkong, but the market fluctuates considerably, according to sanitary and health conditions both in Hongkong and in south China. In view of the poor sanitary conditions in the interior of south China, there is still a great need in that section for purifiers of all kinds.

The kind in most demand is a cresol disinfectant, ranging in strength from 5 to 15 per cent, which can be sold to the Chinese dealers at approximately \$1 a gallon. At present there is one large Hongkong firm purchasing this disinfectant in Shanghai for about 85c. a gallon. After paying freight and shipping charges, the Chinese dealers place the product on the market under their own brands, or "chop," at about \$1.05 a gallon.

To Investigate Florida Peat Deposits

By direction of Secretary Work of the Interior Department, the Bureau of Mines is planning to begin an investigation of the peat deposits of the United States. At the request of Senator Fletcher, this will include an inquiry to determine whether peat exists,

and to what extent, under the soil of Florida.

The bureau has on hand approximately \$50,000 from an appropriation for investigation of lignite and peat. Attention thus far has been devoted to lignite, principally in the Dakotas, the matter of peat having been delayed owing to inquiries into that subject by several European countries, to determine the value of their deposits for fuel and for extraction of byproducts, so that this experience might be available to this country as a foundation for its work.

Tariff Commission Resumes Hearings

The Tariff Commission resumed hearings under the flexible provisions of the tariff law, on Sept. 6. On that day arguments were heard on the subject of brush handles. Hearings scheduled for the next month include: Sept. 10, preliminary hearing on sodium nitrate; Sept. 24, preliminary hearing on briarwood pipes; Sept. 25, argument on casein; Sept. 27, preliminary hearing on raw sugars, and Oct. 1, preliminary hearing on magnesite.

Federal Trade Complaint Against Baer Bros.

The Federal Trade Commission has issued a complaint against Max Baer and A. Baer, manufacturers of paints and allied products, doing business as Baer Bros. According to the complaint, the concern advertises and sells a product not composed wholly of genuine shellac gum, dissolved in alcohol, under the brand and label of "Mongol Shellac," without indicating in any way whatever on the label that the product contains any other gum ingredient or substitute for gum than genuine shellac gum.

Tariff Expert to Investigate Foreign Customs Problems

Henry Chalmers, chief of the division of foreign tariffs of the Commerce Department, will sail this week for Cherbourg, France. Mr. Chalmers is to tour the leading European countries for the purpose of studying the tariff situation and the local customs problems on the admission of American goods into the principal countries of western Europe.

He will visit England, Belgium, France, Switzerland, Italy, Germany, Czechoslovakia and Austria. Until his return in December, Henry L. Deimel, Jr., assistant chief, will be in charge of the division of foreign tariffs.

Gas Association Meeting

Members of the American Gas Association who attend the fall meeting which is to be held at Atlantic City, Oct. 15 to 19 are assured a large, well-planned gathering. Sections on Accounting, Commercial Work, Industrial Gas, Manufacturing Problems and Publicity have been arranged in addition to the technical sessions.



News Notes

The Priestley Medal, awarded for outstanding achievement in chemistry, will be bestowed upon Dr. Ira Remsen, president emeritus of Johns Hopkins University, at a public ceremony in Milwaukee, Wis., Wednesday, Sept. 12, in connection with the 5-day national meeting of the American Chemical Society.

The Beverly Wall Paper Co., Beverly, N. J., has reopened its local plant, closed for some weeks past for the installation of additional equipment and repairs to other machinery. The company moved its plant from New York to this location a number of months ago and has plans for extensive production.

A large American delegation is attending the international foundrymen's congress and exhibition held in Paris, Sept. 2-16, 1923. The Americans' trip is being made under the auspices of the American Foundrymen's Association headed by G. H. Clamer, the president. The French organization in charge of the congress is the Association Technique de Fonderie.

For the 4 months to July, 1923, exports of pulp and paper totaled in value \$45,391,431, against a value of \$35,276,317 in the same period of 1922. Export of pulp wood in this period shows an increase of 84 per cent; for newsprint an increase of 25 per cent; and for wood pulp an increase of 16 per cent over the same period last year. Practically all these exports went to the United States.

Chemical Exposition to Award Certificates of Merit

Exhibits at the 1923 Chemical Exposition which, in the opinion of the management, demonstrate efficiently and in a novel manner the products of the exhibiting company will be awarded a certificate of merit from the exposition following its close. Following plans which have been adopted by world's fairs for many years and at lesser expositions, the Chemical Exposition management has decided to give the merit certificate only to those exhibits considered worthy. They will be in the form of engraved certificates bearing the names of the companies receiving the award. This is the first time that certificates of merit have been used in conjunction with the Chemical Exposition since its inception in 1915.

Alpha Chi Sigma to Meet at Exposition

Last year forty-six Alpha Chi Sigma men attending the Chemical Exposition signed up at Chem. & Met.'s booth. This year again all those of Alpha Chi Sigma attending the show are urged to leave their names at this booth, which

will be headquarters and where one of the fraternity will be constantly in attendance. Registration will be necessary in order to make the necessary arrangements for the annual reunion dinner, which is to be held on Friday evening, Sept. 21. It is proposed this year to make the dinner the best ever. For that reason the committee in charge urges every member to call at the booth for the details as to where, when and how.

Cement Industry Grows in Alabama

The completion and the placing into operation the big cement plants of the Lehigh Portland Cement Co. and the Phoenix Portland Cement Co. make Birmingham, Ala., one of the big cement-producing centers of the United States and the biggest in the South. Each of these plants cost approximately two and a half million dollars, and the two combined will produce something like 3,000,000 bbl. of cement per annum.

Both of these plants are located just on the outskirts of Birmingham, and both near the main line of the Louisville & Nashville R.R. Each plant owns large tracts of lands near by which contain almost unlimited quantities of cement stone of the finest kind, according to experts. Within less than 2 miles of the plants they own extensive beds of shale, which is transported to the plants over short lines of branch railroads.

A few miles out from Birmingham are a half dozen or more smaller cement plants.

Calendar

AMERICAN ELECTROCHEMICAL SOCIETY, forty-fourth meeting, Dayton, Ohio, Sept. 27 to 29.

AMERICAN GAS ASSOCIATION, annual convention, Atlantic City, Oct. 15 to 20.

AMERICAN INSTITUTE OF CHEMICAL ENGINEERS, winter meeting, Washington, D. C., Dec. 5 to 8.

AMERICAN MANAGEMENT ASSOCIATION, Hotel Astor, New York, Oct. 29-31.

AMERICAN MINING CONGRESS, Milwaukee, Wis., Sept. 24 to 27.

AMERICAN SOCIETY OF MECHANICAL ENGINEERS, annual meeting, New York City, Dec. 3 to 6.

AMERICAN SOCIETY OF REFRIGERATING ENGINEERS, annual convention, New York City, Dec. 3 to 5.

AMERICAN SOCIETY FOR STEEL TREATING AND INTERNATIONAL STEEL EXPOSITION, Motor Square Garden, Pittsburgh, Pa., Oct. 8 to 13.

ASSOCIATION OF IRON AND STEEL ELECTRICAL ENGINEERS, convention and exposition, Buffalo, N. Y., Sept. 24 to 28.

NATIONAL ASSOCIATION OF PRACTICAL REFRIGERATION ENGINEERS, fourteenth annual convention, Memphis, Tenn., Dec. 12 to 16.

NATIONAL EXPOSITION OF CHEMICAL INDUSTRIES (NINTH), New York, Sept. 17 to 22.

NATIONAL EXPOSITION OF POWER AND MECHANICAL ENGINEERING, Grand Central Palace, New York, Dec. 3 to 8.

NATIONAL SAFETY COUNCIL, twelfth annual safety convention, Statler Hotel, Buffalo, Oct. 1 to 5.

SOCIETY OF AUTOMOTIVE ENGINEERS, annual meeting, simultaneously with the Detroit Automobile Show, General Motors Bldg., Detroit, Mich., Jan. 22 to 25, 1924.

C. C. Bussey, Engineer of Prominence, Dies

Charles Crocker Bussey, inventor of the Bussey process for low-temperature distillation of coal, died suddenly on Aug. 29, while visiting his family home in Winterport, Me. Mr. Bussey, whose process reached successful commercialization just prior to his death, lived at 12 Gates Ave., Brooklyn, N. Y. His inventions advanced the method of low-temperature distillation of coal in the production of oil, coke, distillates and gas from bituminous coals and oil shales.

Mr. Bussey was a graduate of the Massachusetts Institute of Technology, and during the world war carried on extensive work in an experimental plant in Brooklyn, under the supervision of the War and Navy departments for the production of toluol and fuel oil.

Trade Notes

A revised customs tariff for the Dutch East Indies will be presented to the Volksraad in October. While it is too early for definite information, it is understood that the revision will principally affect luxury articles and that the present limit of 12 per cent ad valorem imposed on imports will not be exceeded.

The Dixie Consolidated Graphite Co. of Birmingham, Ala., will erect a plant at Chattanooga, Tenn. The new plant will produce flake graphite and will have a daily capacity of 15,000 lb.

The Endicott-Johnson Co. has opened its new warehouse at St. Louis. The new warehouse will be used as a distributing center for the Middle West.

James G. Meyer and George W. Retz have been appointed receivers in equity for the New York Rubber Co. The company operated a plant at Beacon, N. Y., and manufactured mechanical rubber goods.

The Duz Co., manufacturer of soaps and soap powders, has purchased the oleomargarine plant of the Downey-Farrel Co. at Chicago.

The Paint, Oil and Varnish Club of New York will hold its first meeting of the 1923-24 season at the Hotel Biltmore, on Thursday evening, Sept. 13. John E. Edgerton, president of the National Association of Manufacturers, will be the principal speaker of the evening.

John J. Watson, Jr., has been elected president of the International Agricultural Corp., succeeding Stephen B. Fleming.

J. E. Bonnabeau, of the general sales department of The Barrett Co., has returned from a business trip to the Middle West.



Facts and Figures
That Influence Trade
in Chemical Products

Market Conditions

Current Prices
Imports and Exports
The Trend of Business

Increased Call for Supplies Reflected in Freer Movement of Chemicals

**Consuming Trades Are Extending Operations—Buying Still Confined
to Nearby Deliveries—Prices Holding Fairly Steady**

LARGELY recovering from the dullness which existed throughout the summer months and are showing more interest in the market for raw materials. While trading is along broader lines, the increased call for stocks is largely for prompt and nearby positions with only a few items attracting inquiries for long time contracts.

The weighted index number for the week shows an increase, although some important chemicals, notably methanol and formaldehyde, were lower in price. Most of the important chemicals are holding steady in price with no marked tendency to move in either direction. Bleaching powder has been one of the weak selections for some weeks and sellers still pursue a policy of dealing on private terms with the result that low prices prevail with no fixed figure as a trading basis.

Considerable interest was shown in possible changes which might follow the catastrophe in Japan but so far as chemicals were concerned this was without effect. Speculative interest was aroused by reports that chemicals used for sanitary purposes would find an increased call for export but nothing developed along that line. Chemicals of Japanese origin which are imported into this country also were in an unchanged position. Japanese arsenic had been offered only in a restricted way in recent weeks and this still was the case but was not intensified by the developments of the week. The fact that Kobe and other leading Japanese ports were not affected prevented any real disturbance in domestic markets for chemicals and allied products.

Imported chemicals, originating in countries outside Japan, showed very little change during the period. In some cases prices abroad are higher than those quoted for spot holdings. Reports that the Ruhr situation would change for the better have been current. Just what influence this would have on market values is of prime interest, with opinions that such a contingency would mean increased production and consequent pressure of offerings. It is also held that an agreement with France would have a beneficial effect on the economic situation in Germany, which in turn would have a stabilizing if not a strengthening effect on values in general.

The lack of interest shown in the market for calcium arsenate indicates that buying is practically over for this season and while no figures are available it is thought that heavy stocks are being carried by some producers.

Acids

Acetic Acid—Fairly large amounts are passing against existing orders and new business is improving slowly, yet the market is reported to be quiet.

Wood Alcohol Lower—Formaldehyde Easier—Tin Crystals and Bichloride of Tin Advance—Arsenic Firm in All Positions—Bleaching Powder Still Weak—Prussiates Quiet—Imported Caustic Potash Easy—Slow Call for Calcium Arsenate.

Some consumers feel that prices are not liable to advance and therefore are not inclined to buy for anything but current needs. Export demand also is quiet. Producing costs are holding up but the undertone is hardly so firm as was the case a short time ago. Asking prices are repeated at: \$3.38@3.63 per 100 lb. for 28 per cent; \$6.78@7.13 per 100 lb. for 56 per cent; \$9.58@9.83 per 100 lb. for 80 per cent; \$12@12.78 per 100 lb. for glacial.

Boric Acid—Moderate sized lots have been moving freely and total business is satisfactory. Export buying has been noted and producers are said to have no heavy accumulations to work off. Prices have been held at relatively low levels for some time due to keen selling competition. This prevents any tendency to advance quotations but lower prices are not anticipated because most sellers already are working at close to production costs. Price schedules quote powdered and crystals at 10@10½c. per lb. in sacks; 10½@11c. per lb. in bbl.; and 11@11½c. per lb. in kegs.

Citric Acid—Consumers have not been in the market to any extent and a very quiet week is reported. Imported acid is offered at 49c. per lb. on shipments from abroad and some holders of spot goods are said to be willing to do business at that price, although up to 50c. per lb. is asked. Domestic

grades are held at 49@50c. per lb. with a fair movement reported against old orders.

Lactic Acid—A greatly improved call for this acid is reported, with large consumers taking on stocks. Imported grades are nominal in view of light offerings and the trading is confined to domestic makes. Prices are on a steady basis with quotations at 4½@5c. per lb. for 22 per cent dark and 5½@6c. per lb. for 22 per cent light; 9½@10c. per lb. for 44 per cent dark and 11½@12c. per lb. for 44 per cent light.

Oxalic Acid—Official figures give imports of oxalic acid in July as 172,925 lb. valued at \$12,892. Offerings of imported are quite free and with demand quiet prices are none too steady. Competition is keen and this has resulted in some business at private terms. Quoted prices are 12½@12½c. per lb. Domestic acid is offered at 12c. per lb. at works.

Tartaric Acid—Imports of tartaric acid in July were 280,000 lb. valued at \$66,520. This represents an average value of approximately 23½c. per lb. Adding duty of 6c. per lb. would make a cost price of 29½c. per lb. Demand for tartaric has been relatively quiet and an easy tone rules in the local market. Imported grades are available at 32@33c. per lb. according to seller. Domestic grades were quiet but quotations were held at 36c. per lb.

Potashes

Bichromate of Potash—A little firmer tone has been noted with reports of a broader inquiry from consumers. The inside price of sellers is given at 10c. per lb. Trading is held to moderate sized quantities but improvement is expected as different consuming trades are expected to operate more actively in the near future.

Caustic Potash—Prices for imported caustic remain irregular. Spot goods are held by different sellers and competition has been keen. Shipments have been quoted at 7c. per lb. and this has tended to weaken prices for spot material with the result that in some directions the spot price was brought down to the level of shipment prices. The general asking price on spot is 7½c. per lb. A fair call is reported for domestic caustic and the quotation is held steady at 9c. per lb., f.o.b. works, with a premium for small lots.

Chlorate of Potash—Prices for imported chlorate of potash are said to show a range according to seller. In many cases the difference in quotations is said to be due to a difference in quality. For goods of standard quality the asking prices range from 7½c. to 8c.



per lb. according to quantity and seller. Demand has been good and some large consumers are reported to have bought heavily in foreign grades. Domestic chlorate also is reported to be firmly held with a good demand. Prices are quoted at 8½c. per lb., at works, and upward, according to quantity.

Potassium Permanganate of Potash—There are offerings of domestic permanganate at 17c. per lb., at works, with producers reported to be in a position to fill orders for round lots. Imported selections are irregular in price. Some holders are reserved but occasional sales at 17c. per lb. have checked advances. The market appeared firmer during the week and 17½c. per lb. was generally held to be an inside price. Shipments from abroad are held above the spot prices and no business is reported in forward positions.

Prussiate of Potash—Red prussiate has not been moving well in recent weeks and prices have reflected this condition. Holders of spot material have been competing keenly. Some sellers held that trading would not be improved by cutting prices but were willing to accept low priced bids when submitted by probable buyers. Sales have been made under 60c. per lb. but quotations are 60@62c. per lb. Yellow prussiate also has been under pressure and prices have varied according to seller. Spot material is generally held at 32@33c. per lb. but shipments have been offered at 29@30c. per lb. and this has cut down demand for spot goods.

Sodas

Acetate of Soda—No improvement is reported in demand for this chemical. Large lots are not interesting buyers and the quiet conditions which have prevailed in recent months still feature the market. Prices are easy with 5c. per lb. quoted for round lots with a range upward depending on quantity.

Bichromate of Soda—While a better inquiry was reported the position of the market was not firm and selling competition was keen enough to give buyers an advantage. On firm bids there were sellers willing to trade at 7½c. per lb. f.o.b. works. In some cases 7½c. per lb. is held as an inside price and prices therefore depended on seller. Some second hands were offering in competition with producers and this added to the easy tone of the market.

Caustic Soda—Export buying is rather light and values f.a.s. are on about the same basis as in preceding weeks. Outside brands are offered at 3.15c. per lb. and standard makes at 3.25@3.30c. per lb. In both cases these prices could probably be shaded on desirable business. A good demand for caustic is reported for domestic trades and this applies both to large lots and to jobbing quantities. Some call also is reported for later deliveries and while spot prices apply on shipments sellers in general do not care to take on orders for distant positions

"Chem. & Met." Weighted Index of Chemical Prices

Base = for 1913-14

This week	170.09
Last week	169.78
Sept., 1922	148.00
Sept., 1921	147.00
Sept., 1920	267.00
Sept., 1919	272.00
Sept., 1918	278.00

While formaldehyde and methanol were lower, the advance in crude cottonseed caused the index number to show a gain of 31 points.

at current price levels. Carlots are held at 3.16c. per lb. at works and recently announced price schedules hold good on jobbing lots.

Fluoride of Soda—The easy position of imported fluoride has failed to promote trading and a quiet market is reported. Offerings of imported were available at 8½@8¾c. per lb. for spot and shipment. Domestic was holding at former price levels of 10@10½c. per lb.

Nitrite of Soda—There was no change in the market during the week. A little better call from consumers was reported but trading was far from active. Prices for imported range from 7½@8c. per lb. according to seller and grade. Producers continue to offer domestic nitrite at 7½c. per lb. at works.

Nitrate of Soda—Exports of nitrate from Chile in July totaled 160,918 metric tons as compared with 145,300 metric tons in June. Total exports for the 7 months ending July 31 were 1,094,718 metric tons. In the first half of August 96,796 tons of nitrate were shipped from Chile, of which 35,560 tons were for the United States. Some improvement is reported in demand for nitrate as some large consumers are said to have placed contracts covering some months ahead. Call for spot material has not broadened out to any extent and the market is in a waiting position. Prices are quotably unchanged at \$2.45 per 100 lb. for spot and prompt.

Prussiate of Soda—It was still possible to do 13½c. per lb. for imported prussiate but the tone appeared firmer and 14c. per lb. was asked by many holders of stocks. Domestic makers were firm at 14c. per lb. for prompt and for deliveries throughout the present month.

Miscellaneous Chemicals

Arsenic—Official returns place imports of white arsenic in July at 1,212,354 lb. valued at \$111,631. Total imports for the first 7 months of the year were 12,558,500 lb. A firm tone ruled in the market with spot material more firmly held and 10½c. per lb. asked. Shipments also are very firm with 10½@10¾c. per lb. asked for foreign and domestic makes. Some interest was shown in Japanese arsenic owing to reports that the earthquake in that country would affect supplies. How-

ever neither production nor facilities for moving stocks were affected. Japanese exporters had been offering in a restricted way recently and apparently are waiting for higher prices.

Bleaching Powder—Chief interest in this market centers in prices. Sellers are trying to reduce holdings and are sacrificing values in order to do so. The quotations as openly quoted are not lived up to and it is impossible to give any price as representing the market. Some goods are said to have been sold at very close to 1c. per lb. and private terms from that figure up to 1½c. per lb. have been the basis of sales.

Borax—A steady undertone featured the market. Granulated and refined, crystals or powdered, in bags, carload lots, 5½c. per lb.; in bbl., 5½c. per lb.

Calcium Arsenate—There is very little call for this material and the market has become a nominal affair. It is held that no heavy buying will be felt as the season is over and contracts are not attracting buyers. There is considerable speculation regarding stocks on hand but no information is available although large amounts are thought to be unsold.

Calcium Chloride—Demand was not so urgent as a short time ago, but with stocks moderate prices ruled steady, leading producers holding out for \$21 per ton on the fused, and \$27 per ton on the granular, f.o.b. works. It is reported that new production will soon come on the market. Recent buying was in the granular which has been finding more of an outlet for road work.

Formaldehyde—First hands lowered the price to 13c. per lb., a decline of ½c.

Fusel Oil—Arrivals of 102 casks from Hamburg were noted during the week. However this had no bearing on the spot market as these goods were sold ahead. Spot offerings of crude were very small and asking prices were given as firm at \$4.25 per gal. Refined was in very limited supply and prices are almost wholly nominal.

Nickel Salts—Moderate improvement was reported in the call for nickel salts. Prices were unaltered, closing on the basis of 10½c. on the double and 11½c. on the single, in bbl.

Tin Salts—The recent uplift in the price of tin strengthened the market for the tin salts and producers announced a new price schedule. Bichloride was raised ½c. per lb., establishing the trading basis at 12@12½c. per lb., in bbl. Tin crystals advanced 1c. per lb., the revised price being 31½c. per lb. Tin oxide, while firmer, was nominally unchanged at 45c. per lb. The average price of Straits tin for August was 39.269c. per lb.

Salammoniac—The market was irregular, especially on the imported material. Importers offered salammoniac for immediate and nearby delivery at 5½@6c. per lb. Domestic was quotably unchanged on the basis of 7½c. per lb. for the white, in bbl.



Coal-Tar Products

Production of Crudes Holds Up Well—Intermediate Makers Show More Buying Interest—Prices Unsettled

MODERATE improvement was reported in the demand for crudes. Makers of intermediates showed more interest in the market, and while bids covering forward delivery material were below sellers' views it was felt that some good orders will be placed soon. Prices remain unsettled. Production of tar oil is heavy, but a relatively small amount is being converted into the higher distillates. The motor fuel situation underwent little change and prices obtained for the lower grades of benzene are anything but satisfactory. Phenol continues to attract attention, and it was reported that several producers were anxious for contract business at concessions from the open market basis. Naphthalene was offered freely and unsettlement in prices prevailed, especially on forward contracts. Cresylic acid was in larger supply. Solvent naphtha ruled firm under scanty offerings, production being well sold up. Pyridine importations have increased, yet prices held firm at the recent advance. A firmer market was reported for orthotoluidine. Aniline oil was steady, despite the routine nature of business. Several handlers entertained firmer views on paranitraniline. Salicylates were inactive, but quotably unchanged.

Aniline Oil and Salt—While demand was slow first hands were firm at 16c. per lb. on the oil, in drums, carload basis, prompt shipment from works. In salt the market was featureless, the price holding around 23c. per lb.

Benzidine—The market was steady at 82@85c. per lb., immediate shipment. On forward deliveries the inside figure might have been shaded. Offerings were moderate.

Benzene—Production is ample for current requirements and in more than one direction selling pressure resulted in offerings at concessions. Producers did not announce an open change in prices, believing that the situation will improve in the near future, especially on the pure grade. Nominally the market for the 90 per cent held at 25c. per gal., tank cars, with the pure at 27c. per gal. The United Kingdom reported improvement in export business. The exports of benzene from the United Kingdom for the 7 months ended July 31 amounted to 632,376 gal., against 46,688 gal. for the corresponding period a year ago.

Creosote—A cargo of creosote oil, consisting of 4,301 tons, arrived at New York last week from Wilhelmshaven. Manchester reported a quiet market, with offerings at 8½d. per gal., bulk basis, works. The exports of tar and creosote oil from the United Kingdom for the 7 months ended with July

amounted to 28,233,554 gal., comparing with 14,965,110 gal. for the corresponding period a year ago.

Cresylic Acid—The market was extremely unsettled on competition among first hands. Prices heard ranged from 65@85c. per gal., depending upon the grade and seller. The market in England has weakened. Demand here was slow.

Naphthalene—There was some talk of lower prices on the different grades of refined naphthalene covering contract business, but producers announced no changes in the selling basis. However, competition for business pending was keen and producers favored with low-priced crude were in a position to take the lead in offering supplies. Chips could be purchased at less than 5c. per lb., nearby delivery, carload lots. Flake on spot held around 6¼@7c. per lb. Crude of good quality was offered at 2½@3c. per lb. Manchester reported offerings of crude for shipment at prices ranging from £7@£13 per ton, depending upon the grade.

Phenol—Prompt shipment U.S.P. phenol was offered at 28c. per lb., round-lot basis. Several holders continued to quote the market at 30@32c., but admitted that prices were easy. On contract there was some pressure to sell and favored buyers could have obtained supplies for 1924 delivery at less than 25c. per lb. Trading was along routine lines only. Consumers take the stand that production next year will be large enough to warrant further reductions in prices.

Financial Notes

The Borne-Scrymser Co. has declared an extra dividend of \$3 and a regular semi-annual dividend of \$4 to stock of record Sept. 22.

Reports from Amsterdam, Holland, state that plans are being worked out for the recapitalization of the Anton Jurgens Margarine Works.

The American Woolen Co. has declared a regular quarterly dividend of 1½ per cent on common, and 1½ per cent on preferred stock of the company.

The Callahan Zinc-Lead Co. reports a deficit of \$42,666 for the quarter ended June 30, compared with net profit of \$48,339 for the preceding quarter.

The Vulcan Detinning Co. for quarter ended June 30, 1923, reports net income of \$62,240, equivalent to \$2.57 a share earned on \$2,419,400 combined preferred and class "A" preferred stock.

Alcohol

The feature in the market was the reduction in prices for methanol. In order to stimulate business producers revised the trading basis on the 95 per cent material to \$1.05 per gal., in cooperage, and the 97 per cent grade to \$1.07 per gal. No changes occurred in the market for denatured alcohol. The undertone was steady and leading interests reported business on the basis of 38@40c. per gal., in drums, on the 190 proof, formula No. 1, the inside figure prevailing on carload lots. Ethyl spirits held at \$4.75@\$4.80 per gal., in bbl., U.S.P. 190 proof.

Canadian Oleomargarine Act Operative

Inasmuch as the oleomargarine act has not been extended by the Canadian Parliament, the importation of that commodity into Canada, as well as its manufacture within that country, will not be permitted after Aug. 31. The sale, offering for sale and having in possession for sale of oleomargarine are permitted until March 1, 1924.

Latest Quotations on Industrial Stocks

	Last Week	This Week
Air Reduction	66½	65
Allied Chem. & Dye	68	68
Allied Chem. & Dye pfd.	*108	*108
Am. Ag. Chem.	17	16½
Am. Ag. Chem. pfd.	41	41
American Cotton Oil	7	7½
American Cotton Oil pfd.	23	24½
American Cyanamid	*59	*61½
Am. Drug Synd.	4½	4½
Am. Linseed Co.	21	20½
Am. Linseed pfd.	40	39
Am. Smelting & Refining Co.	60½	58½
Am. Smelting & Refining pfd.	97½	97
Archer-Daniels Mid. Co., w.l.	28	27
Archer-Daniels Mid. Co., pfd.	93	90
Atlas Powder	57½	55½
Casell Co. of Am.	*62	*62
Certain-Teed Products	30	30
Commercial Solvents "A"	32	33
Corn Products	128½	128½
Corn Products pfd.	*120	*117½
Davison Chem.	52	49
Dow Chem. Co.	*45	*45
Du Pont de Nemours	131	134½
Du Pont de Nemours db.	84½	85
Freeport-Texas Sulphur	13	14½
Glidden Co.	*81	*8
Grasselli Chem.	*132	*132
Grasselli Chem. pfd.	*105	*105
Hercules Powder	110	*110
Hercules Powder pfd.	107	*107
Heyden Chem.	*2	*2
Int'l Ag. Chem. Co.	3½	4
Int'l Ag. Chem. pfd.	111	12½
Int'l Nickel	13	13
Int'l Nickel pfd.	79½	79
Int'l Salt	*89½	*89½
Mathieson Alkali	46	43
Merck & Co.	*78	*78
National Lead	130	126½
National Lead pfd.	*113½	*113½
New Jersey Zinc	152	152
Parke, Davis & Co.	*78½	*78½
Pennsylvania Salt	*81	*81
Procter & Gamble	*128	*128
Sherwin-Williams	28½	*28½
Sherwin-Williams pfd.	102	*102
Tenn. Copper & Chem.	91	91
Texas Gulf Sulphur	59½	57½
Union Carbide	56½	57
United Drug	78½	80
United Dyewood	43	44½
U. S. Industrial Alcohol	55½	54½
U. S. Industrial Alcohol pfd.	*100	*100
Va.-Car. Chem. Co.	12½	12½
Va.-Car. Chem. pfd.	34½	33

*Nominal. Other quotations based on last sale.



Vegetable Oils and Fats

Active Call for Crude Cottonseed—Linseed Irregular—Coconut Higher—Tallow and Greases Advance

WITH the exception of linseed and China wood oils the market presented a firm appearance and numerous advances were reported. The feature was the strong position of crude cottonseed for immediate and nearby shipment from Southern points. Lard compound makers were buyers, but covering by shorts also was in evidence. Coconut oil was firm in all quarters, reflecting continued strength in copra, and sales went through at higher figures. Corn oil was marked up on the strength in cottonseed. There was some improvement in the demand for crude soya bean oil. Linseed oil was irregular, especially on futures, and several round lots changed hands at concessions. China wood oil also was unsettled. The advance in tallow stimulated buying in palm oils.

Cottonseed Oil—The market for both refined and crude oil established new highs for the movement. October option prime summer yellow sold at 11c. per lb., while March was traded in as high as 10c. per lb. The shortage in old crop oil was more apparent and compound makers were willing buyers of crude for immediate as well as nearby shipment from the South at the higher prices asked. Immediate crude sold at 9½c. per lb., tank car basis, f.o.b. mills Southeast, while bids at 9c. for late September shipment were turned down. October crude settled nominally at 8½@8¾c. per lb., Texas. Bleachable oil was in scanty supply and the market closed firm at 11c. per lb., tank cars, New Orleans, and 11½c. per lb., tank cars, New York. The demand for lard compound was fairly active and, with pure lard higher, producers raised the price of the cottonseed oil product to 12½@13c. per lb. Sentiment toward the close was mixed. Cotton news was rather bullish, but it was feared that prevailing high prices for oil will check consumption. There was some good selling of March oil on the advance and one operator was credited with disposing of more than 25,000 bbl. at prices ranging from 9½@10c. per lb. Stocks of lard at the leading Western markets were reduced by 16,000,000 lb. in the past month. Hogs were easier on liberal receipts.

Linseed Oil—September shipment oil was quotably unchanged at 83c. per gal., carloads, cooperage basis. On futures the market was irregular. Inquiry was about for October forward deliveries and it was reported that one block of approximately 3,000 bbl., calling for October-November-December delivery, sold at 80c. per gal. Another round lot sold for November forward shipment, deliveries extending into 1924, at 79c. per gal., cooperage basis. At the close several crushers refused to shade 82c. on November-December

business, while 84c. was the nominal price asked on October oil. The flaxseed markets were firmer and this steadied the undertone. Crop developments, taken as a whole, were favorable. Cables from the Argentine reported that the area devoted to flaxseed will be larger than last season. One semi-official estimate placed the area at 4,821,000 acres. News out of India reported no changes of consequence, shipments continuing at the rate of 200,000 bu. a week. In the American Northwest harvesting is in progress and receipts have increased. Demand for new crop seed from crushers has been active, which supported prices. Stocks of seed at Minneapolis were 31,211 bu., against 6,761 bu. a year ago. There was a quiet but steady market for cake.

China Wood Oil—It was reported that 25 cars of wood oil sold for shipment over the next 5 months on the basis of 19½c. per lb., sellers' tanks, f.o.b. Pacific coast. There were offerings of prompt shipment from the coast at 20½c. per lb. Immediate shipment from New York, tank cars, was available at 21½c. per lb. For spot oil in cooperage prices ranged from 23@23½c. per lb. The market was unsettled.

Coconut Oil—A Canadian soap-maker purchased 3 cars of Ceylon type oil, October-November-December shipment from the coast, at 8½c. per lb., tank car basis, an advance of ½c. for the week. In New York the market settled at 8½c. asked, with a possibility that bids at 8½c. might go through. Cebu copra closed at 5½c. asked, c.i.f. coast. Last sales were put through at 4½c. Copra cake for export was offered at \$30 per ton, f.a.s. New York.

Corn Oil—Crude corn oil sold at 9c. per lb., sellers' tanks, f.o.b. shipping point, an advance of ½c. Crude oil in cooperage sold at 10c. per lb., f.o.b. New York, but toward the close the asking price was raised to 10½c.

Olive Foots—Prime green Italian foots sold at prices ranging from 8½@8¾c. per lb. The market was irregular.

Palm Oils—There was some buying interest in Niger for shipment. Niger for shipment settled at 6.85c. per lb., c.i.f. New York. Lagos for shipment was firm at 7½c. per lb. The foreign markets were higher, but this was offset by the decline in exchange.

Rapeseed Oil—English refined oil was offered at 76c. per gal., in bbl., immediate delivery. On futures prices ranged from 72@73c. per gal., as to position. Demand for forward material was good.

Soya Bean Oil—Inquiry showed improvement and the market closed firmer on spot, asking prices ranging from 9@9½c. per lb., sellers' tanks, duty paid. Two bulk shipments arrived from Dairen.

Menhaden Oil—Fishing returns were good. Prices ruled steady in sympathy with competing oils and 40c. was asked for crude, tank car basis, f.o.b. factory.

Oleo Stearine—Sales of carload lots were reported at 12c. per lb., an advance of ½c.

Tallow and Greases—Offerings of extra tallow were light and bids at 7½c. turned down. Early in the week more than 500,000 lb. sold at 7½c. Yellow grease was advanced to 6½@7½c. per lb. London tallow auction was 6d. to 1s. higher.

Miscellaneous Materials

Antimony—The market was steady, Chinese brands closing at 7½@7¾c. per lb. Chinese needle antimony, lump, nominal 5.50c. per lb. Standard powdered needle, 200 mesh, 6@6½c. White oxide, Chinese, guaranteed 99 per cent, 7½@8½c. per lb.

Barytes—It was reported that large consumers asked that shipments be deferred because of a slackening in demand for finished products. Prices asked closed unchanged. Crude held at \$7@10 per ton, with white floated at \$28@30 per ton, f.o.b. St. Louis.

Glycerine—The market for chemically pure glycerine was unsettled on lack of active buying interest. Eastern refiners held out for 17c., but Western operators offered supplies at slight concessions. Dynamite closed at 16c. bid, with sales at this figure early in the week. Crude soap-lye, basis 80 per cent, loose, settled at 11@11½c. per lb., with the undertone steady. Saponification was nominal at 12½c., loose.

Lithopone—Producers reported unchanged trading conditions, with prices steady on the basis of 7c. per lb., carload lots, in bags.

Naval Stores—No improvement was reported in export demand and, with domestic business confined chiefly to small lots, the undertone was barely steady. Spirits of turpentine held at 95c. per gal. Rosins were in moderate demand, but with a fair movement of goods against existing contracts, prices ruled steady on the basis of \$5.75 per bbl. on the lower grades.

Waxes—There was an advance of 3c. per lb. in Japan wax, closing prices ranging from 18@20c. Crude beeswax was nominally unchanged at 21@26c. per lb., as to grade. Paraffine was steady, but quotably unchanged. Car-nauba was easier on spot.

White Lead—The market was steady in sympathy with the metal; corrodors reported prices unchanged, standard dry (basic carbonate) holding at 9½c. per lb., in casks, carload lots. Pig lead was unchanged at 6½c. per lb.

Zinc Oxide—The movement of zinc oxide into consuming channels was fair for this season of the year. The tone was steady, leading interests quoting on the basis of 8c. per lb. for the lead free, American process, carload lots, October-November-December shipment.



Imports at the Port of New York

August 31 to September 6

ACIDS—Cresylic—2 dr., London, Celluloid Co.; 70 dr., Glasgow, Caldwell & Co.; 50 dr., Glasgow, Order. **Diethylbarbituric**—5 cs., Southampton, Order. **Phosphoric**—40 dr., Hamburg, Hummel & Robinson. **Tartaric**—340 keg, Hamburg, W. Benkert & Co.

ALCOHOL—265 bbl. denatured, Arecibo, C. Esteve; 8 cs. and 4 dr. amylic, Hamburg, Order.

AMMONIA—14 dr. liquid, Aberdeen, J. H. Meyer Bros.; 120 bbl. spirits, Hamburg, Order; 85 cs. muriate, Bristol, C. de P. Field Co.; 20 cs. carbonate, Liverpool, Order.

ANTIMONY SULPHIDE—34 cs., London, L. H. Butcher & Co.

ANTIMONY—34 cs., Newcastle-on-Tyne, E. Hills' Son & Co.

ALBUMEN—42 cs., Tientsin, Jardine, Matheson & Co.; 78 cs., Tientsin, Frazar & Co.

ARSENIC—233 bbl., Frontera, American Smelting & Refining Co.; 179 bbl., Frontera, Order; 5 cs., London, Order; 49 bbl., Piraeus, Order; 100 cs., Kobe, A. Klipstein & Co.; 600 cs., Kobe, Takata & Co.; 195 cs., Kobe, S. W. Bridges & Co.; 112 cs., Kobe, Order.

ARCHIL—10 cs., London, A. Deronde & Co.; 5 cs., London, Oakes Mfg. Co.; 5 cs., London, W. Mohrmann & Co.

BARIUM HYDRATE—15 cs., Hamburg, Order.

BARIUM SUPEROXIDE—33 cs., Hamburg, W. A. Brown & Co.

BARYTES—100 tons carbonate, Newcastle-on-Tyne, Bankers Trust Co.; 300 kg., Bremen, N. Y. Trust Co.

BAUXITE—Quantity in bulk, Paramaribo, A. M. Kohler.

BRONZE POWDER—2 cs., Bremen, O. Hommel Co.; 12 cs., Hamburg, Order; 15 cs., Bremen, B. F. Drakenfeld & Co.; 14 cs., Hamburg, J. E. Mandlik; 26 cs., Hamburg, Uhlfelder & Co.

CALCIUM CHLORIDE—49 dr., Hamburg, A. Hirsch & Son; 48 dr., Hamburg, Order.

CALCIUM CARBIDE—500 dr., Antwerp, Iron & Ore Corp.

CASEIN—129 kg., Rio de Janeiro; 701 kg., Buenos Aires, Order.

CARBON BICHLORIDE—59 cs., Hamburg, Roessler & Hasslacher Chemical Co.

CHALK—1,600 kg. and 200 bbl., Antwerp, Bankers Trust Co.; 400 kg. ground, Antwerp, Reichard-Coulston, Inc.; 1,000 kg., Antwerp, Order; 45 pkg., Kobe, Cooper & Cooper, Inc.; 25 cs., Bristol, H. J. Baker & Bros.

CHEMICALS—5 cs., Antwerp Guaranty Trust Co.; 143 dr., Hamburg, Roessler & Hasslacher Chemical Co.; 63 cs., Hamburg, C. D. Stone & Co.; 350 kg., Glasgow, Brown Bros. & Co.; 324 kg., Glasgow, Bankers Trust Co.; 8 cs., Havre, Ciba Co.; 134 kg., Hamburg, Roessler & Hasslacher Chemical Co.

CAMPHOR—200 bbl., Hamburg, Philadelphia National Bank; 50 cs. crude, Hong Kong, Irving Bank-Col. Trust Co.; 510 cs., Shanghai, Order; 400 cs., Kobe, Order.

CREOSOTE—4,301 tons oil in bulk, Wilhelmshaven, American Creosoting Co.

COLORS—11 cs., aniline, Hamburg, Kuttroff, Pichardt & Co.; 12 cs. do., Hamburg, H. A. Metz & Co.; 12 cs. aniline, Antwerp, Geigy Co.; 7 bbl. aniline, Antwerp, American Express Co.; 22 cs. dry, Southampton, R. F. Downing & Co.; 14 cs., Havre, Ackerman Color Co.; 5 cs. aniline, Havre, Order; 4 cs., Havre, Carbic Color Co.; 200 kg. earth, Leghorn, Reichard-Coulston, Inc.; 6 cs. aniline, Havre, Ciba Co.; 32 cs. aniline, Havre, Sandoz Chemical Works; 7 dr. aniline, Buenos Aires, National Aniline & Chemical Co.; 8 pkg. aniline, Hamburg, Franklin Imp. & Exp. Co.

COPRA—27 kg., Humacao, Franklin Baker Co.; 107 kg., Morant Bay, Order.

COPPER OXIDE—34 cs., London, Order.

CREAM TARTAR—100 cs., Marseilles, Brown Bros. & Co.; 100 keg, Genoa, Archibald Lewis & Co.; 10 keg, Genoa, Order.

CUTCH—3 cs., Rangoon, Order.

DIVI-DIVI—667 kg., Pampatar, Eggers & Heinlein.

EPSOM SALT—21 bbl., Hamburg, Innis, Spelden & Co.

FERROMANGANESE—50 cs., Havre, De Consey Browne.

FULLERS EARTH—770 kg., London, L. A. Salomon & Bros.; 600 kg., Bristol, L. A. Salomon & Bros.

FUSEL OIL—10 cs., Hamburg, Guaranty Trust Co.; 7 cs., Hamburg, Order; 45 bbl., Hamburg, Order; 5 dr., Sourabaya, Gebrüder de Groot; 35 bbl., Hamburg, Order.

GLAUBER SALT—200 kg., Hamburg, Order.

GLYCERINE—100 dr. crude, London, Order.

GRAPHITE—897 bbl., Moji, Order; 3,750 kg., Kobe, Mitsui & Co.

GUMS—105 kg. copal, Antwerp, Brown Bros. & Co.; 360 kg., Antwerp, Central Union Trust Co.; 268 kg. copal, Antwerp, Chemical National Bank; 24 cs. copal, Marseilles, Order; 94 kg. copal, Antwerp, Order; 100 cs. damar, Batavia, W. Schall & Co.; 100 cs. damar, Chemical National Bank; 307 kg. yacca, Adelaide, Baring Bros. & Co.; 235 kg. tragacanth, London, Brown Bros. & Co.

IRON OXIDE—40 bbl., Malaga, C. B. Chrystal Co.; 158 bbl., Malaga, C. K. Williams & Co.; 299 bbl., Malaga, C. J. Osborn; 33 bbl., Malaga, National City Bank; 50 bbl., Marseilles, Reichard-Coulston, Inc.; 328 bbl., Malaga, Hummel & Robinson; 30 bbl., Malaga, Order; 50 cs., Liverpool, Battery Park National Bank; 10 cs., Liverpool, J. A. McNulty; 10 cs., Liverpool, Order.

LITHOPONE—100 cs., Antwerp, A. Klipstein & Co.; 100 cs., Antwerp, E. M. & F. Waldo.

LOGWOOD—30 cs. extract, Kingston, A. S. Lascelles & Co.; 10 cs. extract, Havre, Order.

MAGNESIUM—10 cs. calcined, Newcastle-on-Tyne, Order; 150 kg., Hamburg, H. J. Baker & Bros.; 600 bbl. chloride, Hamburg, Order; 5 cs. superoxide, Hamburg, Intercean Fwdg. Co.

MAGNESITE—375 kg. and 230 bbl. Rotterdam, Innis, Spelden & Co.; 112 bbl., Rotterdam, Spelden-Whitfield & Co.

MENTHOL—50 cs., Yokohama, S. Minra; 10 cs., London, Stallman & Co.

NICKEL SULPHATE—43 cs., Bristol, Order.

NAPHTHALENE—320 kg., Hamburg, White Tar Co.; 300 kg., Hamburg, Order; 579 kg., Antwerp, Order.

OSHER—726 cs., Marseilles, Reichard-Coulston, Inc.; 351 cs., Marseilles, J. Lee Smith & Co.; 43 cs., Marseilles, Iron & Ore Corp.; 25 cs., Marseilles, Order.

OILS—Cod—100 cs., St. Johns, R. Badcock & Co.; 100 bbl., Kobe, Cook & Swan Co. **China Wood**—293 cs., Hankow, W. S. Patterson & Co.; 150 cs., Hankow, Sina Java Handelsvereniging, Inc.; 180 cs., Hankow, Brown Bros. & Co.; 300 cs., Hankow, Balfour, Williamson & Co. **Palm**—309 cs., West Coast Africa, Bank Francaise de Afrique Equatoriale; 15 cs., West Coast Africa, A. D. Strauss & Co.; 610 cs., Rotterdam, African & Eastern Trading Corp. **Perilla**—800 bbl., Darien, Brown, Edwards & Co. **Rapeseed**—200 bbl., Hull Order. **Sesame**—275 bbl., Marseilles, Order. **Soya Bean**—743 tons (bulk), Dairen, Order; 1,144 tons (bulk), Dairen, Mitsubishi Shoji Kaisha. **Seal**—544 cs., St. Johns, Bowring & Co.; 100 cs., St. Johns, R. Badcock & Co. **Sperm**—30 bbl., Glasgow, Order.

OIL SEEDS—Castor—138 kg., West Coast Africa, Suffern Trading Co. **Linseed**—57,768 kg. and 2,630,921 kilos (bulk), Rosario, Spencer Kellogg & Sons.

POTASSIUM SALTS—100 kg. muriate, Bremen, Potash Importing Corp. of Amer-

ica; 1,000 kg. sulphate, Bremen, Potash Importing Corp. of America; 500 cs. chlorate, Marseilles, Order; 30 cs. bromide, Hamburg, Seaboard National Bank; 1,890 kg. muriate and a quantity of manure salts in bulk, Autwerp, Society Comm. des Potasses d'Alsace; 372 bbl. salts, Constantinople, Arcos, Ltd.; 60 dr. permanganate, Hamburg, Brown Bros. & Co.; 75 dr. caustic, Hamburg, Peters, White & Co.; 18 keg prussiate, Liverpool, C. Tennant Sons & Co.

PHOSPHORUS—2 cs., Hamburg, Order; 3 cs. trichloride, Hamburg, Order.

PITCH—136 bbl., Hull, Order.

PYRIDINE—11 dr., Rotterdam, Order; 4 dr., Hamburg, R. W. Greeff & Co.; 8 dr., Hamburg, Order.

QUEBRACHO—14,168 kg., Buenos Aires, International Products Co.; 5,004 kg., Buenos Aires, Fourth Atlantic National Bank of Boston; 1,052 kg., Buenos Aires, N. Y. Trust Co.; 974 kg., Buenos Aires, Irving Bank-Col. Trust Co.

SHELLAC—199 kg., London, Order; 350 kg., Calcutta, London & Brazilian Bank; 200 kg., Calcutta, Standard Bank of South Africa; 100 kg., Calcutta, Brown Bros. & Co.; 100 kg., Calcutta, British Bank of South America; 200 kg., Calcutta, Bracklay's Bank; 2,707 kg., 112 cs., 20 chests, Calcutta, Order; 275 kg. seedlac, 10 kg. refuse, Calcutta, Order; 5 cs. garnet, Calcutta, Order; 562 kg., Southampton, Rogers-Pyatt Shellac Co.; 105 kg., Southampton, Order; 15 cs., Rotterdam, C. F. Gerlach; 23 kg., Hamburg, Irving Bank-Col. Trust Co.; 38 kg., Hamburg, Kasabier-Chatfield Shellac Co.

SODIUM SALTS—85 cs. yellow prussiate, Rotterdam, Order; 57 cs. phosphate, Antwerp, A. Klipstein & Co.; 348 cs. cyanide, Havre, Hardy & Rupert; 131 cs. hyposulphite, Marseilles, Order; 81 dr. caustic, Hamburg, A. Klipstein & Co.; 161 dr. caustic, Hamburg, Goldschmidt Corp.; 100 dr. sulphide, Bristol, R. F. Downing & Co.; 120 cs. hyposulphate, Marseilles, Order.

SPAR—732,097 kilos, Hamburg, American Steel Export Co.

TALC—500 kg., Genoa, Bankers Trust Co.; 300 kg., Genoa, C. B. Chrystal & Co.

TANKAGE—420 kg. Havana, J. V. Suarez.

TARTAR—661 kg., Marseilles, Royal Baking Powder Co.; 356 kg., Alicante, C. Pfizer & Co.; 196 kg., Rotterdam, C. Pfizer & Co.; 414 kg., Buenos Aires, Anglo-South American Bank; 100 kg., Marseilles, C. Pfizer & Co.

TETRACHLORETHANE—268 cs., Hamburg, Roessler & Hasslacher Chemical Co.

VALONIA—3,098 kg., Constantinople, African & Eastern Trading Co.; 1,497 kg., Smyrna, Order.

WAXES—24 kg. beeswax, Constantinople, Order; 445 kg. carnauba, Ceara, Lazard Freres; 43 kg. carnauba, Ceara, London & Brazilian Bank; 23 kg. carnauba, Ceara, Int'l Acceptance Bank; 535 kg. do., Ceara, Order; 113 kg. do., Recife, National City Bank; 94 kg. beeswax and 84 kg. carnauba, Rio de Janeiro, American Trading Co.; 112 kg. carnauba, Rio de Janeiro, Order; 17 pkg. bees, Puerto Plata, Order.

WOOL GREASE—50 bbl., Hull, American Trust Co.; 100 bbl., Hull, Marden-Wild Corp.

ZINC WHITE—100 cs., Antwerp, E. M. & F. Waldo.

Gasoline Stocks Reduced in July

A reduction in the stocks of gasoline from a sixty days' supply on July 1 to fifty-four days' supply on Aug. 1 is shown in statistics compiled by the Department of the Interior from reports of 282 operating refineries throughout the country. Stocks on hand at refineries on Aug. 1 amounted to 1,165,389,340 gal., a decrease of 98,193,788 gal. from stocks held July 1.



Current Prices in the New York Market

For Chemicals, Oils and Allied Products

General Chemicals

Acetone, drums.	lb.	\$0.25 - \$0.25
Acid, acetic, 28%, bbl.	100 lb.	3.38 - 3.50
Acetic, 56%, bbl.	100 lb.	6.75 - 7.00
Acetic, 80%, bbl.	100 lb.	9.58 - 9.83
Glacial, 99%, bbl.	100 lb.	12.00 - 12.78
Acetic anhydride, 85%, dr.	lb.	.38 - .40
Boric, bbl.	lb.	.10 - .11
Citric, kegs.	lb.	.49 - .50
Formic, 85%,	lb.	.12 - .14
Gallie, tech.	lb.	.45 - .50
Hydrofluoric, 52%, carboys	lb.	.11 - .12
Lactic, 44%, tech., light,	lb.	.11 - .12
bbl.	lb.	.05 - .06
22% tech., light, bbl.	100 lb.	.90 - 1.00
Muriatic, 18% tanks	100 lb.	1.00 - 1.10
Muriatic, 20% tanks	100 lb.	1.00 - 1.10
Nitric, 36%, carboys	lb.	.04 - .05
Nitric, 42%, carboys	lb.	.06 - .06
Oleum, 20%, tanks	ton	18.50 - 19.00
Oxalic, crystals, bbl.	lb.	.12 - .12
Phosphoric, 50%, carboys	lb.	.07 - .08
Pyrogallie, resublimed	lb.	1.50 - 1.60
Sulphuric, 60%, tanks	ton	11.00 - 12.00
Sulphuric, 60%, drums	ton	13.00 - 14.00
Sulphuric, 66%, tanks	ton	15.00 - 16.00
Sulphuric, 66%, drums	ton	20.00 - 21.00
Tannic, U.S.P., bbl.	lb.	.65 - .70
Tannic, tech., bbl.	lb.	.45 - .50
Tartaric, imp., powd., bbl.	lb.	.33 - .34
Tartaric, domestic, bbl.	lb.	.36 - .36
Tungstic, per lb.	lb.	1.10 - 1.20
Alcohol, butyl, drums, f.o.b.	lb.	.26 - .28
Alcohol ethyl (Cologne	gal.	4.78 - .
spirit), bbl.	gal.	4.75 - .
Ethyl, 190 p.f. U.S.P., bbl.	gal.	4.75 - .
Alcohol, methyl (see Methanol)		
Alcohol, denatured, 190 proof		
No. 1, special bbl.	gal.	.44 - .
No. 1, 190 proof, special, dr.	gal.	.38 - .
No. 1, 188 proof, bbl.	gal.	.45 - .
No. 1, 188 proof, bbl.	gal.	.39 - .
No. 5, 188 proof, bbl.	gal.	.43 - .
No. 5, 188 proof, dr.	gal.	.37 - .
Alum, ammonia, lump, bbl.	lb.	.03 - .04
Potash, lump, bbl.	lb.	.03 - .04
Chrome, lump, potash, bbl.	lb.	.06 - .07
Aluminum sulphate, com.		
bags	100 lb.	1.40 - 1.50
Iron free bags	lb.	2.40 - 2.50
Aqua ammonia, 26%, drums	lb.	.07 - .07
Ammonia, anhydrous, cyl.	lb.	.30 - .30
Ammonium carbonate, powd.	lb.	.09 - .10
casks, imported	lb.	.09 - .10
Ammonium carbonate, powd.	lb.	.13 - .14
domestic, bbl.	lb.	.13 - .14
Ammonium nitrate, tech.	lb.	.10 - .11
casks	lb.	.10 - .11
Amly acetate tech., drums	gal.	4.50 - 4.75
Antimony Sulphuret, golden	lb.	.19 - .20
Arsenic, white, powd., bbl.	lb.	.10 - .11
Arsenic, red, powd., kegs.	lb.	.15 - .15
Barium carbonate, bbl.	ton	65.00 - 70.00
Barium chloride, bbl.	ton	82.00 - 90.00
Barium dioxide, drums	lb.	.18 - .18
Barium nitrate, casks	lb.	.08 - .08
Blanc fixe, dry, bbl.	lb.	.04 - .04
Bleaching powder, f.o.b. wks.		
drums	100 lb.	1.50 - 1.75
Spot N. Y. drums	100 lb.	2.00 - 2.10
Borax, bbl.	lb.	.05 - .05
Bromine, cases	lb.	.28 - .30
Calcium acetate, bags	100 lb.	4.00 - 4.05
Calcium arsenate, dr.	lb.	.13 - .14
Calcium carbide, drums	lb.	.05 - .05
Calcium chloride, fused, dr. wks.	ton	21.00 - .
Gran. drums works	ton	27.00 - .
Calcium phosphate, mono,		
bbl.	lb.	.06 - .07
Camphor, cases	lb.	.92 - .93
Carbon bisulphide, drums	lb.	.07 - .07
Carbon tetrachloride, drums	lb.	.09 - .09
Chalk, precip.—domestic,		
light, bbl.	lb.	.04 - .04
Domestic, heavy, bbl.	lb.	.03 - .03
Imported, light, bbl.	lb.	.04 - .05
Chlorine, liquid, tanks, wks.	lb.	.05 - .05
Cylinders, 100 lb., wks.	lb.	.06 - .06
Cylinders, 100 lb., spot	lb.	.09 - .09
Chloroform, tech., drums	lb.	.28 - .32
Cobalt oxide, bbl.	lb.	2.10 - 2.25
Copperas, bulk, f.o.b. wks.	ton	20.00 - 21.00
Copper carbonate, bbl.	lb.	.18 - .19
Copper cyanide, drums	lb.	.47 - .50
Coppersulphate, dom., bbl.	100 lb.	5.10 - 5.25
Imp. bbl.	100 lb.	4.60 - 4.65
Cream of tartar, bbl.	lb.	.24 - .26
Epsom salt, dom., tech.	100 lb.	1.75 - 2.00
Epsom salt, imp., tech.	100 lb.	.90 - 1.00
Epsom salt, U.S.P., dom.	100 lb.	2.25 - 2.50
bbl.	100 lb.	.13 - .15
Ether, U.S.P., resale, dr.	lb.	.13 - .15
Ethyl acetate, 85%, drums	gal.	.80 - .81

THESE prices are for the spot market in New York City, but a special effort has been made to report American manufacturers' quotations whenever available. In many cases these are for material f.o.b. works or on a contract basis and these prices are so designated. Quotations on imported stocks are reported when they are of sufficient importance to have a material effect on the market. Prices quoted in these columns apply to large quantities in original packages.

Ethyl acetate,		
ether, 98% to 100%, gal.	\$0.95 - \$1.00	
Formaldehyde, 40%, bbl.	lb.	.13 - .13
Fullers earth—imp., powd., net	ton	30.00 - 32.00
Fusel oil, ref., drums	gal.	.25 - .25
Fusel oil, crude, drums	gal.	4.25 - .
Glaucous salt, wks., bags	100 lb.	1.20 - 1.40
Glaucous salt, imp., bags	100 lb.	.90 - .95
Glycerine, c.p., drums extra	lb.	.17 - .17
Glycerine, dynamite, drums	lb.	.16 - .16
Glycerine, crude 80%, loose	lb.	.11 - .11
Iron oxide, red, casks	lb.	.12 - .18
Lead:		
White, basic carbonate, dry,	lb.	.09 - .09
casks	lb.	.08 - .09
White, basic sulphate, casks	lb.	.11 - .11
White, in oil, kegs	lb.	.10 - .10
Red, dry, casks	lb.	.13 - .14
Red, in oil, kegs	lb.	.14 - .14
Lead acetate, white crys., bbl.	lb.	.14 - .14
Brown, broken, casks	lb.	.13 - .13
Lead arsenate, powd., bbl.	lb.	.18 - .20
Lime-Hydrated, lg. wks.	ton	10.50 - 12.50
Bbl., wks.	ton	18.00 - 19.00
Lime, Lump, bbl.	280 lb.	3.63 - 3.65
Litharge, comm., casks	lb.	.10 - .10
Lithophone, bags	lb.	.07 - .07
in bbl.	lb.	.07 - .07
Magnesium carb., tech., bags	lb.	.08 - .08
Methanol, 95%, bbl.	gal.	1.05 - .
Methanol, 97%, bbl.	gal.	1.07 - .
Methyl-acetone, 'tks.	gal.	1.15 - .
Nickel salt, double, bbl.	lb.	.10 - .10
Nickel salts, single, bbl.	lb.	.11 - .11
Phosgene	lb.	.60 - .75
Phosphorus, red, cases	lb.	.35 - .40
Phosphorus, yellow, cases	lb.	.35 - .40
Potassium bichromate, casks	lb.	.10 - .10
Potassium bromide, gran.	lb.	.19 - .20
Potassium carbonate, 80-85%,		
calcined, casks	lb.	.06 - .06
Potassium chlorate, powd.	lb.	.07 - .07
Potassium cyanide, drums	lb.	.47 - .52
Potassium, first sort, casks	lb.	.07 - .08
Potassium hydroxide (caustic		
potash) drums	lb.	.07 - .09
Potassium iodide, cases	lb.	3.65 - 3.75
Potassium nitrate, bbl.	lb.	.07 - .09
Potassium permanganate,		
drums	lb.	.17 - .17
Potassium prussiate, red,		
casks	lb.	.60 - .63
Potassium prussiate, yellow,		
casks	lb.	.32 - .33
Salammoniac, white, gran.		
casks, imported	lb.	.05 - .06
Salammoniac, white, gran.		
bbl., domestic	lb.	.07 - .07
Gray, gran., casks	lb.	.08 - .09
Salsoda, bbl.	100 lb.	1.20 - 1.40
Salt cake (bulk)	ton	26.00 - 28.00
Soda ash, light, 58% flat,		
bags, contract	100 lb.	1.45 - 1.50
Soda ash, light, 58% flat,		
bags, resale	100 lb.	1.70 - 1.75
Soda ash, dense, bags, con-		
tract, basis 58%	100 lb.	1.51 - .
Soda ash, dense, in bags,		
resale	100 lb.	1.85 - 1.90
Soda, caustic, 76%, solid,		
drums	100 lb.	3.16 - .
Soda, caustic, ground and		
flake, contracts	100 lb.	3.60 - 3.85
Soda, caustic, solid, 76%		
f. a. s. N. Y.	100 lb.	3.15 - 3.25
Sodium acetate, works, bags	lb.	.05 - .05
Sodium bicarbonate, bbl.	100 lb.	2.00 - 2.50
Sodium bichromate, casks	lb.	.07 - .07
Sodium bisulphate (niter cake)	ton	6.00 - 7.00
Sodium bisulphite, powd.,		
U.S.P., bbl.	lb.	.04 - .04
Sodium chlorate, kegs	lb.	.06 - .07
Sodium chloride, long ton	12.00 - 13.00	
Sodium cyanide, cases	lb.	.19 - .22

Sodium fluoride, bbl.	lb.	\$0.08 - \$0.10
Sodium hyposulphite, bbl.	lb.	.02 - .03
Sodium nitrite, casks	lb.	.07 - .07
Sodium peroxide, powd., cases	lb.	.28 - .30
Sodium phosphate, dibasic,		
bbl.	lb.	.03 - .04
Sodium prussiate, yel. drums	lb.	.13 - .14
Sodium salicylic, drums	lb.	.40 - .45
Sodium silicate (40%, drums)	100 lb.	.75 - 1.15
Sodium silicate (60%, drums)	100 lb.	1.75 - 2.00
Sodium sulphide, fused, 60-		
62% drums	lb.	.03 - .04
Sodium sulphite, crys., bbl.	lb.	.03 - .03
Strontium nitrate, powd., bbl.	lb.	.10 - .11
Sulphur chloride, yel. drums	lb.	.04 - .05
Sulphur, crude	ton	18.00 - 20.00
At mine, bulk	ton	16.00 - 18.00
Sulphur, flour, bag	100 lb.	2.25 - 2.35
Sulphur, roll, bag	100 lb.	2.00 - 2.10
Sulphur dioxide, liquid, cyl.	lb.	.08 - .08
Tin bichloride, bbl.	lb.	.12 - .12
Tin oxide, bbl.	lb.	.45 - .45
Tin crystals, bbl.	lb.	.31 - .32
Zinc carbonate, bags	lb.	.14 - .14
Zinc chloride, gran, bbl.	lb.	.06 - .06
Zinc cyanide, drums	lb.	.37 - .38
Zinc oxide, lead free, bbl.	lb.	.08 - .08
5% lead sulphate, bags	lb.	.07 - .07
10 to 35 % lead sulphate,		
bags	lb.	.07 - .07
French, red seal, bags	lb.	.09 - .09
French, green seal, bags	lb.	.10 - .10
French, white seal, bbl.	lb.	.12 - .12
Zinc sulphate, bbl.	100 lb.	2.50 - 3.00

Coal-Tar Products

Alpha-naphthol, crude, bbl.	lb.	\$0.60 - \$0.70
Alpha-naphthol, ref., bbl.	lb.	.65 - .80
Alpha-naphthylamine, bbl.	lb.	.34 - .36
Aniline oil, drums	lb.	.16 - .16
Aniline salts, bbl.	lb.	.22 - .23
Anthracene, 80%, drums	lb.	.75 - .80
Anthracene, 80%, imp.		
drums, duty paid	lb.	.65 - .70
Anthraquinone, 25%, paste,		
drums	lb.	.80 - .85
Benzaldehyde U.S.P., carboys	lb.	1.50 - .
f.f.c. drums	lb.	1.60 - .
tech., drums	lb.	.75 - .
Benzene, pure, water-white,		
tanks and drums	gal.	.27 - .32
Benzene, 90%, tanks & drums	gal.	.25 - .30
Benzidine base, bbl.	lb.	.80 - .85
Benzidine sulphate, bbl.	lb.	.75 - .75
Benzoic acid, U.S.P., kegs	lb.	.80 - .85
Benzoate of soda, U.S.P., bbl.	lb.	.65 - .70
Benzyl chloride, 95-97%, ref.		
drums	lb.	.45 - .45
Benzyl chloride, tech., drums	lb.	.30 - .35
Beta-naphthol, tech., bbl.	lb.	.22 - .23
Beta-naphthylamine, tech.	lb.	.75 - .80
Cresol, U.S.P., drums	lb.	.25 - .29
Ortho-cresol, drums	lb.	.28 - .32
Cresylic acid, 97%, works		
drums	gal.	.80 - .85
95-97%, drums, works	gal.	.70 - .75
Dichlorobenzene, drums	lb.	.06 - .08
Diethylaniline, drums	lb.	.50 - .60
Dimethylaniline, drums	lb.	.41 - .42
Dinitrobenzene, bbl.	lb.	.19 - .20
Dinitrochlorobenzene, bbl.	lb.	.21 - .22
Dinitronaphthalene, bbl.	lb.	.30 - .32
Dinitrophenol, bbl.	lb.	.35 - .40
Dinitrotoluene, bbl.	lb.	.20 - .22
Dip oil, 25%, drums	gal.	.25 - .30
Diphenylamine, bbl.	lb.	.50 - .52
H-acid, bbl.	lb.	.75 - .80
Meta-phenylenediamine, bbl.	lb.	1.00 - 1.05
Miehlers ketone, bbl.	lb.	3.00 - 3.50
Monochlorobenzene, drums	lb.	.08 - .10
Monochlorobenzene, drums	lb.	.95 - 1.10
Naphthalene, flake, bbl.	lb.	.06 - .07
Naphthalene, balls, bbl.	lb.	.07 - .07
Naphthionate of soda, bbl.	lb.	.58 - .65
Naphthionic acid, crude, bbl.	lb.	.55 - .60
Nitrobenzene, drums	lb.	.10 - .12
Nitro-naphthalene, bbl.	lb.	.30 - .35
Nitro-toluene, drums	lb.	.13 - .14
N-W acid, bbl.	lb.	1.25 - 1.30
Ortho-amidophenol, kegs	lb.	2.30 - 2.35
Ortho-dichlorobenzene, drums	lb.	.15 - .17
Ortho-nitrophenol, bbl.	lb.	1.20 - 1.30
Ortho-nitrotoluene, drums	lb.	.10 - .12
Ortho-toluidine, bbl.	lb.	.16 - .18
Para-amidophenol, base, kegs	lb.	1.35 - .
Para-amidophenol, HCl, kegs	lb.	1.55 - .
Para-dichlorobenzene, bbl.	lb.	.17 - .20
Paranitroaniline, bbl.	lb.	.72 - .74
Para-nitrotoluene, bbl.	lb.	.60 - .65
Para-phenylenediamine, bbl.	lb.	1.45 - 1.50
Para-toluidine, bbl.	lb.	.90 - .95
Phthalic anhydride, bbl.	lb.	.35 - .38
Phenol, U.S.P., dr.	lb.	.28 - .32
Picric acid, bbl.	lb.	.20 - .22
Pyridine, dom., drums	gal.	nominal
Pyridine, imp., drums	gal.	4.75 - 5.00
Resorcinol, tech., kegs	lb.	1.40 - 1.50

Resorcinol, pure, kegs.....	lb.	\$2.25 -
R-salt, bbl.....	lb.	.55 - \$0.65
Salicylic acid, tech., bbl.....	lb.	.32 -
Salicylic acid, U.S.P., bbl.....	lb.	.35 -
Solvent naphtha, water-white, tanks.....	gal.	.27 -
Crude, tanks.....	gal.	.24 -
Sulphanilic acid, crude, bbl.....	lb.	.18 - .20
Thiocarbamide, kegs.....	lb.	.35 - .38
Tolidine, bbl.....	lb.	1.00 - 1.05
Toluidine, mixed, kegs.....	lb.	.30 - .35
Toluene, tank cars.....	gal.	.30 - .32
Toluene, drums.....	gal.	.34 - .36
Xylidine, drums.....	lb.	.50 -
Xylene, pure, drums.....	gal.	.60 - .65
Xylene, com., drums.....	gal.	.34 -
Xylene, com., tanks.....	gal.	.29 -

Naval Stores

Rosin B-D, bbl.....	280 lb.	\$5.75 - \$5.80
Rosin E-I, bbl.....	280 lb.	5.90 -
Rosin K-N, bbl.....	280 lb.	5.90 - 6.15
Rosin W.G.-W.W., bbl.....	280 lb.	6.50 - 7.25
Wood rosin, bbl.....	280 lb.	5.90 - 6.00
Turpentine, spirits of, bbl.....	gal.	.95 -
Wood, steam dist., bbl.....	gal.	.77 -
Wood, dest. dist., bbl.....	gal.	.65 -
Pine tar pitch, bbl.....	200 lb.	5.50 -
Tar, kiln burned, bbl.....	500 lb.	11.00 -
Retort tar, bbl.....	500 lb.	11.00 -
Rosin oil, first run, bbl.....	gal.	.42 -
Rosin oil, second run, bbl.....	gal.	.48 -
Rosin oil, third run, bbl.....	gal.	.52 -
Pine oil, steam dist., bbl.....	gal.	.70 -
Pine oil, pure, dest. dist., bbl.....	gal.	.65 -
Pine tar oil, ref., bbl.....	gal.	.48 -
Pine tar oil, crude, tanks f.o.b. Jacksonville, Fla., bbl.....	gal.	.32 - .32
Pine tar oil, double ref., bbl.....	gal.	.75 -
Pine tar, ref., thin, bbl.....	gal.	.25 -
Pine wood creosote, ref., bbl.....	gal.	.52 -

Animal Oils and Fats

Degras, bbl.....	lb.	\$0.04 - \$0.04
Greas, yellow, bbl.....	lb.	.06 - .07
Lard oil, Extra No. 1, bbl.....	gal.	.86 - .88
Lard oil, 20 deg. bbl.....	gal.	1.20 - 1.25
No. 1, bbl.....	gal.	.92 - .94
Oleo Stearine.....	lb.	.12 - .12
Oleo oil, No. 1, bbl.....	lb.	.09 - .10
Red oil, distilled, d.p. bbl.....	lb.	.09 - .10
Raponified, bbl.....	lb.	.07 - .08
Tallow, extra, loose, bbl.....	gal.	.84 - .86
Tall - w oil, acidless, bbl.....	gal.	.84 - .86

Vegetable Oils

Castor oil, No. 3, bbl.....	lb.	\$0.13 -
Castor oil, No. 1, bbl.....	lb.	.13 - .23
Chinawood oil, bbl.....	lb.	.09 - .10
Cocunut oil, Ceylon, bbl.....	lb.	.08 - .08
Ceylon, tanks, N.Y., bbl.....	lb.	.10 - .10
Cocunut oil, Cochinchina, bbl.....	lb.	.10 - .10
Corn oil, crude, bbl.....	lb.	.09 -
Crude, tanks, (f.o.b. mill), bbl.....	lb.	.09 -
Cottonseed oil, crude (f.o.b. mill), tanks.....	lb.	.09 - .12
Summer yellow, bbl.....	lb.	.12 - .13
Winter yellow, bbl.....	lb.	.12 - .13
Linseed oil, raw, ear lots, bbl.....	gal.	.88 -
Raw, tank cars (dom.), bbl.....	gal.	.83 -
Boiled, ears, bbl. (dom.), bbl.....	gal.	.90 -
Olive oil, denatured, bbl.....	gal.	1.10 - 1.12
Sulphur, (foot) bbl.....	lb.	.08 - .08
Palm, Lagos, casks.....	lb.	.07 -
Niger casks.....	lb.	.06 -
Palm kernel, bbl.....	lb.	.08 -
Peanut oil, crude, tanks (mill), bbl.....	lb.	.13 - .14
Peanut oil, refined, bbl.....	lb.	.14 - .15
Perilla, bbl.....	lb.	.14 - .15
Rapeseed oil, refined, bbl.....	gal.	.76 -
Rapeseed oil, blown, bbl.....	gal.	.82 -
Sesame, bbl.....	lb.	.11 - .11
Soya bean (Manchurian), bbl.....	lb.	.10 -
Tank, f.o.b. Pacific coast.....	lb.	.08 -
Tank, (f.o.b. N.Y.).....	lb.	.09 -

Fish Oils

Cod, Newfoundland, bbl.....	gal.	\$0.61 - \$0.63
Menhaden, light pressed, bbl.....	gal.	.63 -
White bleached, bbl.....	gal.	.65 -
Blown, bbl.....	gal.	.69 -
Crude, tanks (f.o.b. factory), bbl.....	gal.	.40 -
Whale No. 1 crude, tanks, coast.....	lb.	.76 - .78
Winter, natural, bbl.....	gal.	.79 - .80
Winter, bleached, bbl.....	gal.	.79 - .80

Oil Cake and Meal

Cocunut cake, bags.....	ton	\$30.00 - \$31.00
Copra, sun dried, bags, (e.i.f.).....	lb.	.05 -
Sun dried Pacific coast.....	lb.	.05 -
Cottonseed meal, f.o.b. mills.....	ton	40.00 -
Linseed cake, bags.....	ton	36.00 -
Linseed meal, bags.....	ton	40.00 - 42.00

Dye & Tanning Materials

Albumen, blood, bbl.....	lb.	\$0.45 - \$0.50
Albumen, egg, tech, kegs.....	lb.	.95 - 1.00
Cochineal, bags.....	lb.	.34 - .36
Cutch, Borneo, bales.....	lb.	.04 - .04
Cutch, Rangoon, bales.....	lb.	.13 - .14
Dextrine, corn, bags.....	100 lb.	3.79 - 4.06
Dextrine, gum, bags.....	100 lb.	4.14 - 4.34
Divi-divi, bags.....	ton	38.00 - 39.00
Fustic, sticks.....	ton	30.00 - 35.00
Fustic, chips, bags.....	lb.	.04 - .05
Logwood, sticks.....	ton	26.00 - 28.00
Logwood, chips, bags.....	lb.	.02 - .03
Sumac, leaves, Sicily, bags.....	ton	78.00 - 80.00

Sumac, ground, bags.....	ton	\$72.00 - \$75.00
Sumac, domestic, bags.....	ton	40.00 - 42.00
Starch, corn, bags.....	100 lb.	3.12 - 3.39
Tapioca flour, bags.....	lb.	.07 - .07

Extracts

Arehil, cone, bbl.....	lb.	\$0.18 - \$0.22
Chestnut, 25% tannin, tanks.....	lb.	.02 - .03
Divi-divi, 25% tannin, bbl.....	lb.	.04 - .05
Fustic, crystals, bbl.....	lb.	.20 - .22
Fustic, liquid, 42% bbl.....	lb.	.08 - .09
Gambier, liq., 25% tannin, bbl.....	lb.	.08 - .09
Hemlock, 25% tannin, bbl.....	lb.	.14 - .18
Hyperic, solid, drums.....	lb.	.03 - .04
Hyperic, liquid, 51% bbl.....	lb.	.24 - .26
Logwood, crys., bbl.....	lb.	.09 - .10
Logwood, liq., 51% bbl.....	lb.	.16 - .17
Quebracho, solid, 65% tannin, bbl.....	lb.	.08 - .09
Sumac, dom., 51% bbl.....	lb.	.04 - .05
Sumac, dom., 51% bbl.....	lb.	.06 - .07

Dry Colors

Blacks-Carbons, bags, f.o.b. works, spot.....	lb.	\$0.17 - \$0.21
Lampblack, bbl.....	lb.	.12 - .40
Mineral, bulk.....	ton	35.00 - 45.00
Blues-Bronze, bbl.....	lb.	.50 - .55
Prussian, bbl.....	lb.	.50 - .55
Ultramarine, bbl.....	lb.	.08 - .35
Browns, Sienna, Ital., bbl.....	lb.	.06 - .14
Sienna, Domestic, bbl.....	lb.	.03 - .04
Umber, Turkey, bbl.....	lb.	.04 - .04
Greens-Chrome, C.P. Light, bbl.....	lb.	.32 - .34
Chrome, commercial, bbl.....	lb.	.12 - .12
Paris, bulk.....	lb.	.28 - .30
Reds, Carmine No. 40, tins.....	lb.	4.50 - 4.70
Oxide red, casks.....	lb.	.10 - .14
Para toner, kegs.....	lb.	1.00 - 1.10
Vermilion, English, bbl.....	lb.	1.20 - 1.25
Yellow, Chrome, C.P. bbls.....	lb.	.20 - .21
Ocher, French, casks.....	lb.	.02 - .03

Waxes

Bayberry, bbl.....	lb.	\$0.27 - \$0.28
Beeswax, crude, bags.....	lb.	.21 - .26
Beeswax, refined, light, bags.....	lb.	.32 - .34
Beeswax, pure white, cases.....	lb.	.40 - .41
Candelilla, bags.....	lb.	.22 - .23
Carnauba, No. 1, bags.....	lb.	.42 - .42
No. 2, North Country, bags.....	lb.	.23 - .23
No. 3, North Country, bags.....	lb.	.17 - .17
Japan, cases.....	lb.	.18 - .19
Montan, crude, bags.....	lb.	.05 - .05
Paraffine, crude, match, 105-110 m.p., bbl.....	lb.	.04 - .04
Crude, scale 124-126 m.p., bags.....	lb.	.02 - .03
Ref., 118-120 m.p., bags.....	lb.	.03 - .03
Ref., 125 m.p., bags.....	lb.	.03 - .03
Ref., 128-130 m.p., bags.....	lb.	.03 - .03
Ref., 133-135 m.p., bags.....	lb.	.04 - .04
Ref., 135-137 m.p., bags.....	lb.	.05 - .05
Stearic acid, agle pressed, bags.....	lb.	.12 - .12
Double pressed, bags.....	lb.	.12 - .13
Triple pressed, bags.....	lb.	.14 - .14

Fertilizers

Ammonium sulphate, bulk, f.o.b. works.....	100 lb.	\$3.20 - \$3.25
F.a.s. double bags.....	100 lb.	3.50 - 3.55
Blood, dried, bulk.....	unit	4.00 -
Bone, raw, 3 and 50, ground.....	ton	27.00 - 30.00
Fish scrap, dom., dried, wks.....	unit	3.75 -
Nitrate of soda, bags.....	100 lb.	2.45 - 2.52
Tankage, high grade, f.o.b. Chicago.....	unit	3.60 - 3.75
Phosphate rock, f.o.b. mines, Florida pebble, 68-72%.....	ton	4.00 - 4.50
Tennessee, 78-80%.....	ton	8.00 - 8.25
Potassium muriate, 80% bags.....	ton	34.55 -
Potassium sulphate, bags basis 90%.....	ton	43.67 -
Double manure salt.....	ton	25.72 -
Kainit.....	ton	7.22 -

Crude Rubber

Para-Upriver fine.....	lb.	\$0.28 -
Upriver coarse.....	lb.	.23 -
Upriver cauchoo ball.....	lb.	.24 -
Plantation-First latex crepe.....	lb.	.29 -
Ribbed smoked sheets.....	lb.	.29 -
Brown crepe, thin, clean.....	lb.	.28 -
Amber crepe No. 1.....	lb.	.28 -

Gums

Copal, Congo, amber, bags.....	lb.	\$0.12 - \$0.13
East Indian, bold, bags.....	lb.	.23 - .23
Manila, pale, bags.....	lb.	.20 - .20
Pontinak, No. 1 bags.....	lb.	.20 - .20
Damar, Batavia, cases.....	lb.	.28 - .28
Singapore, No. 1, cases.....	lb.	.32 - .33
Singapore, No. 2, cases.....	lb.	.23 - .24
Kauri, No. 1, cases.....	lb.	.68 - .70
Ordinary chips, cases.....	lb.	.23 - .24
Manjak, Barbados, bags.....	lb.	.09 - .09

Shellac

Shellac, orange fine, bags.....	lb.	\$0.61 - \$0.62
Orange superfine, bags.....	lb.	.63 - .64
A. C. garnet, bags.....	lb.	.59 -
Bleached, bonedry.....	lb.	.70 - .71
Bleached, fresh.....	lb.	.58 - .59
T. N., bags.....	lb.	.58 - .59

Miscellaneous Materials

Asbestos, crude No. 1, f.o.b. Quebec.....	sh. ton	\$375.00 - \$500.00
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Asbestos, shingle, f.o.b. Quebec.....	sh. ton	\$55.00 - \$60.00
Asbestos, cement, f.o.b. Quebec.....	sh. ton	20.00 - 25.00
Barytes, grd., white, f.o.b. mills, bbl.....	net ton	16.00 - 20.00
Barytes, grd., off-color, f.o.b. mills bulk.....	net ton	13.00 - 15.00
Barytes, floated, f.o.b. St. Louis, bbl.....	net ton	28.00 -
Barytes, crude f.o.b. mines, bulk.....	net ton	8.00 - 10.00
Cascine, bbl, tech.....	lb.	.13 - .15
China clay (kaolin) crude, f.o.b. Ga.....	net ton	6.00 - 8.00
Washed, f.o.b. Ga.....	net ton	8.00 - 9.00
Powd., f.o.b. Ga.....	net ton	14.00 - 20.00
Crude f.o.b. Va.....	net ton	6.00 - 8.00
Ground, f.o.b. Va.....	net ton	13.00 - 19.00
Imp., lump, bulk.....	net ton	15.00 - 20.00
Imp., powd.....	net ton	45.00 - 50.00
Feldspar, No. 1 pottery.....	long ton	7.50 -
No. 2 pottery.....	long ton	6.00 -
No. 1 soap.....	long ton	8.50 -
No. 1 Canadian, f.o.b. mill.....	long ton	18.00 - 20.00

Graphite, Ceylon, lump, first quality, bbl.....	lb.	.06 - .06
Ceylon, chip, bbl.....	lb.	.04 - .05
High grade amorphous, crude.....	ton	15.00 - 30.08
Gum arabic, amber, sorts, bags.....	lb.	.14 - .14
Gum tragacanth, sorts, bags.....	lb.	.50 - .55
No. 1, bags.....	lb.	1.50 - 1.60
Kieselguhr, f.o.b. Cal.....	ton	40.00 - 42.00
F.o.b. N. Y.....	ton	50.00 - 55.00
Magnesite, crude, f.o.b. Cal.....	ton	14.00 - 15.00
Pumice stone, imp., casks.....	lb.	.03 - .05
Dom., lump, bbl.....	lb.	.05 - .05
Dom., ground, bbl.....	lb.	.05 - .06
Silica, glass sand, f.o.b. Ind.....	ton	2.00 - 2.50
Silica, sand blast, f.o.b. Ind.....	ton	2.50 - 5.00
Silica, amorphous, 250-mesh, f.o.b. Ill.....	ton	17.00 - 17.50
Silica, glass sand, f.o.b. Ill.....	ton	1.50 - 3.00
Soapstone, coarse, f.o.b. Vt., bags.....	ton	7.00 - 8.00
Talc, 200 mesh, f.o.b. Vt., bags, extra.....	ton	6.00 - 8.00
Talc, 200 mesh, f.o.b. Ga., bags.....	ton	7.00 - 9.00
Talc, 200 mesh, f.o.b. Los Angeles, bags.....	ton	18.00 - 20.00

Mineral Oils

Crude, at Wells

Pennsylvania.....	bbl.	\$2.75 -
Corning.....	bbl.	1.60 -
Cabell.....	bbl.	1.50 -
Somersett.....	bbl.	1.40 -
Illinois.....	bbl.	1.67 -
Indiana.....	bbl.	1.68 -
Kansas and Oklahoma, 28 deg. bbl.....	bbl.	1.20 -
California, 35 deg. and up.....	bbl.	1.04 -

Gasoline, Etc.

Motor gasoline, steel bbls.....	gal.	\$0.19 -
Naphtha, V. M. & P. deod, steel bbls.....	gal.	.18 -
Kerosene, ref. tank wagon.....	gal.	.14 -
Bulk, W.W. delivered, N.Y. gal.....	gal.	.06 -
Lubricating oils:		
Cylinder, Penn., dark.....	gal.	.21 -
Bloomless, 300/31 grav.....	gal.	.18 -
Paraffin, pale.....	gal.	.15 - .17
Spindle, 200, pale.....	gal.	.20 - .21
Petrolatum, amber, bbls.....	lb.	.03 - .04
Paraffine wax (see waxes)		

Refractories

Bauxite brick, 56% Al ₂ O ₃ , f.o.b. Pittsburgh.....	1,000	\$140-145
Chrome brick, f.o.b. Eastern shipping points.....	ton	50-52
Chrome cement, 40-50% Cr ₂ O ₃ , 40-45% Cr ₂ O ₃ , sacks, f.o.b. Eastern shipping points.....	ton	23-27
Fireclay brick, 1st. quality, 9-in. shapes, f.o.b. Ky. wks.....	1,000	45-48
2nd. quality, 9-in. shapes, f.o.b. wks.....	1,000	38-42
Magnesite brick, 9-in. straight (f.o.b. wks.).....	ton	65-68
9-in. arches, wedges and keys.....	ton	80-85
Scraps and splits.....	ton	85
Silica brick, 9-in. sizes, f.o.b. Chicago district.....	1,000	53-55
Silica brick, 9-in. sizes, f.o.b. Birmingham district.....	1,000	53-54
F.o.b. Mt. Union, Pa.....	1,000	45-47
Silicon carbide refract. brick, 9-in.....	1,000	1,100.00

Ferro-Alloys

Ferrotitanium, 15-18% f.o.b. Niagara Falls, N. Y.....	ton	\$200.00 - \$225.00
Ferrochromium, per lb. of Cr, 1-2% C.....	lb.	.28 - .30
4-6% C.....	lb.	.12 -
Ferromanganese, 78-82% Mn, Atlantic seab. duty paid.....	gr. ton	117.50 -
Spiegeleisen, 19-21% Mn.....	gr. ton	45.00 - 47.00
Ferromolybdenum, 50-60% Mo, per lb. Mo.....	lb.	2.00 - 2.50
Ferroaluminum, 10-12%.....	gr. ton	43.00 - 50.00
50%.....	gr. ton	85.00 -



Ferrotungsten, 70-80%, per lb. of W..... lb.	\$0.85 @ \$0.95
Ferro-uranium, 35-50% of U. per lb. of U..... lb.	4.50 -
Ferrovanadium, 30-40%, per lb. of V..... lb.	3.50 - 4.50

Ores and Semi-finished Products

Bauxite, dom. crushed dried, f.o.b. shipping points..... ton	\$5.50 - \$8.75
Chrome ore Calif. concen- trates, 50% min. Cr ₂ O ₃ ton	22.00 - 23.00
C.i.f. Atlantic seaboard... ton	21.00 - 25.00
Coke, fdry., f.o.b. ovens... ton	5.50 - 5.75
Coke, furnace, f.o.b. ovens... ton	4.75 - 5.00
Fluorspar, gravel, f.o.b. mines, Illinois..... ton	23.50 -
Ilmenite, 52% TiO ₂ lb.	.014 - .014
Manganese ore, 50% Mn c.i.f. Atlantic seaboard... unit	.40 -
Manganese ore, chemical (MnO ₂)..... ton	75.00 - 80.00
Molybdenite, 85% MoS ₂ , per lb. MoS ₂ , N. Y..... lb.	.75 -
Monasite, per unit of ThO ₂ , c.i.f. Atl. seaboard... lb.	.06 - .08
Pyrites, Span., fines, c.i.f. Atl. seaboard... unit	.114 - .12
Pyrites, Span., furnace size, c.i.f. Atl. seaboard... unit	.114 - .12
Pyrites, dom. fines, f.o.b. mines, Ga..... unit	.12 -
Rutile, 95% TiO ₂ lb.	.12 -
Tungsten, scheelite, 60% WO ₃ and over..... unit	9.50 - 10.00
Tungsten, wolframite, 60% WO ₃ unit	8.75 - 9.00
Uranium ore (carnotite) per lb. of U ₃ O ₈ lb.	3.50 - 3.75
Uranium oxide, 96% per lb. U ₃ O ₈ lb.	2.25 - 2.50
Vanadium pentoxide, 99% lb..... lb.	12.00 - 14.00
Vanadium ore, per lb. V ₂ O ₅ lb.	.75 - 1.00
Zircon..... ton	50.00 -

Non-Ferrous Materials

	Cents per Lb.
Copper, electrolytic.....	131
Aluminum, 98 to 99%.....	26-27
Antimony, wholesale, Chinese and Japanese.....	71-71
Nickel, virgin metal.....	27-29
Nickel, ingot and shot.....	30-32
Monel metal, shot and blocks.....	32-00
Monel metal, ingots.....	38-00
Monel metal, sheet bars.....	45-00
Tin, 5-ton lots, Straits.....	41-75
Lead, New York, spot.....	5-75
Lead, E. St. Louis, spot.....	6-65
Zinc, spot, New York.....	6-90
Zinc, spot, E. St. Louis.....	6-55

Other Metals

Silver (commercial)..... oz.	\$0.621
Cadmium..... lb.	1.00
Bismuth (500 lb. lot)..... lb.	2.55
Cobalt..... lb.	3.00-3.25
Magnesium, ingots, 99%..... lb.	1.25-.....
Platinum..... oz.	116.00
Iridium..... oz.	275.00 @ 300.00
Palladium..... oz.	80.00
Mercury..... 75 lb.	62.00-64.00

Finished Metal Products

	Warehouse Price Cents per Lb.
Copper sheets, hot rolled.....	22.75
Copper bottoms.....	31.50
Copper rods.....	23.00
High brass wire.....	20.25
High brass rods.....	18.00
Low brass wire.....	21.75
Low brass rods.....	22.00
Brass tubing.....	24.25
Brass bronze tubing.....	28.50
Seamless copper tubing.....	27.00
Seamless high brass tubing.....	25.50

OLD METALS—The following are the dealers' purchasing prices in cents per pound:

Copper, heavy and crucible.....	9.25 @ 9.50
Copper, heavy and wire.....	11.25 @ 11.50
Copper, light and bottoms.....	10.25 @ 10.50
Lead, heavy.....	5.25 @ 5.50
Lead, ton.....	3.25 @ 3.375
Brass, heavy.....	6.25 @ 6.50
Brass, light.....	5.25 @ 5.50
No. 1 yellow brass turnings.....	6.00 @ 6.25
Zinc scrap.....	3.50 @ 3.75

Structural Material

The following base prices per 100 lb. are for structural shapes 3 in. by 1/2 in. and larger, and plates 1/2 in. and heavier, from jobbers' warehouses in the cities named:

	New York	Chicago
Structural shapes.....	\$3.64	\$3.64
Soft steel bars.....	3.54	3.54
Soft steel bar shapes.....	3.54	3.54
Soft steel bands.....	4.39	4.39
Plates, 1/2 to 1 in. thick.....	3.64	3.64

Industrial

Financial, Construction and Manufacturing News

Construction and Operation California

SANTA PAULA—G. S. Stoll and C. F. Baudisch are planning for the organization of a company to construct and operate a local plant for the manufacture of tile products. A site is being selected. The initial plant will have four or more kilns and is estimated to cost in excess of \$50,000, with equipment.

VERNON—The California Metal Enameling Co., East 51st St., is completing plans for the erection of a new addition to its plant and will soon break ground. It will be 1-story, 50x120 ft. and 60x75 ft., estimated to cost about \$40,000. Hamm & Grant, Inc., Ferguson Bldg., Los Angeles, is engineer.

SAN FRANCISCO—The Great Western Smelting & Refining Co., 75 Folsom St., has taken bids and will soon break ground for the erection of a new 1-story addition, 137x275 ft., at Spear and Folsom Sts., estimated to cost \$75,000. Morrow & Garren, Chronicle Bldg., are architects.

Delaware

WILMINGTON—The Speakman Co., Spruce and 30th Sts., manufacturer of enameled iron sanitary ware, etc., has commenced the erection of a 3-story addition to its plant, 60x75 ft., to cost about \$52,000, for which a general contract was recently awarded to John E. Healy & Son, 707 Tatnall St.

Florida

SOUTH JACKSONVILLE—The Leesburg Fibre Pulp & Paper Co., Leesburg, Fla., has preliminary plans under consideration for the construction of a new local plant for the manufacture of paper products, utilizing fiber pulp produced at the Leesburg works. The main structure will be 50x300 ft., supplemented with a number of smaller buildings, including power house, estimated to cost approximately \$500,000, including machinery. Gilbert D. Leach, secretary and treasurer, is in charge.

PENSACOLA—P. S. Lavender, Tuscaloosa, Ala., is perfecting plans for the organization of a company to construct and operate a local pottery for the manufacture of flower pots, flue lining and kindred specialties. A site will be selected at an early date.

Georgia

BOLTON—The National Paper Co. has awarded a contract to the West Point Iron Workers, Inc., West Point, Ga., for the construction of a new 1-story building at its plant, for general operating service.

PORT WENTWORTH—The Savannah Sugar Refining Co., Savannah, has work under way on the installation of additional machinery at its local refining plant, including improvements and repairs in present equipment and buildings, and plans to have the plant ready for production at an early date.

SAVANNAH—The Swift Fertilizer Works, Inc., has acquired the local plant of the American Fertilizer Co., Lathrop Ave. Immediate possession will be taken and extensions and improvements made, including the installation of additional equipment. It is proposed to remove considerable machinery now at the Hutchinson Island plant to the new location. Operations will be commenced at an early date.

Illinois

CHICAGO—The Wisconsin Steel Works, Inc., 106th St. and Torrence Ave., has completed plans and will commence the construction of a new 1-story addition, 40x128 ft., estimated to cost about \$25,000.

Kentucky

BROWNSVILLE—The Natural Rock Asphalt Co., recently organized with a paid-up capital of \$350,000, has tentative plans under consideration for the construction of a new plant on property acquired in Edmonson County, estimated to cost close to \$100,000, including equipment. C. K. Kirkpatrick is president.

Louisiana

SWARTZ—The J. M. Huber Carbon Co., operating a local plant for the production of carbon black, is planning for the rebuilding of the portions of its works recently destroyed by fire with loss estimated at \$25,000.

Maryland

BALTIMORE—The Paper Products Co., Wheeler Ave. and Franklin St., has preliminary plans under consideration for the rebuilding of the portion of its works, destroyed by fire Aug. 23, with loss approximating \$150,000, including machinery and equipment. Joseph W. Smith is general manager.

Massachusetts

EAST BRAINTREE—The Cities Service Refining Co., Boston, has perfected plans for the operation of its local refining plant, to specialize in the production of lubricating oils, being the only works of this kind in this district. It is proposed to develop maximum production at an early date.

Michigan

BAY CITY—The Wildman Rubber Co. has resumed construction operations on its new local plant, temporarily discontinued some weeks ago, and will rush the structure to completion. It will be 3-story, estimated to cost about \$75,000, to be equipped for the manufacture of automobile tires and other rubber products. Machinery will be installed at an early date and plant production commenced.

DETROIT—Plans are being drawn by the Austin Co., Penobscot Bldg., engineer and contractor, for the construction of three new foundries at the local plant of the Cadillac Motor Car Co., 2060 Clark St., for the production of steel and other metal castings. The structures will cost in excess of \$350,000.

HOUGHTON—The Calumet & Hecla Co., Inc., has tentative plans under consideration for extensions and improvements in its smelting plant at Houghton, near Houghton, for considerable increase in production.

LANSING—The State Department of Geology has been instructed to make investigations regarding a state-owned cement manufacturing plant, with byproducts works in the same district for the production of fertilizers, etc., estimated to cost in excess of \$800,000, including equipment. The cement mill will comprise a number of buildings with power house, and will be operated under the direction of the State Highway Department.

RIVER ROUGE—Plans are being drawn for the construction of a new 1-story foundry, 600x1,800 ft., at the local plant of the Ford Motor Co., for the production of steel and other metal castings, estimated to cost in excess of \$500,000, with equipment. Preliminary plans are also in preparation for the construction of a coal byproducts plant at the same works, to cost close to \$800,000, with machinery. Albert Kahn, 1000 Marquette Bldg., Detroit, is architect for both projects.

GAY—The Mohawk Mining Co. has work in progress on a new steam-operated re-grinding mill at its local copper properties.

Mississippi

GULFPORT—The Lawler-Navek Mfg. Co., recently organized with a capital of \$60,000, is perfecting plans for the establishment



of a local plant for the manufacture of aluminum and kindred metal products. Stamping, drilling, polishing and other machinery will be installed. Charles E. Navek, one of the heads of the company, will act as engineer.

CRYSTAL SPRINGS—The Hazlehurst Oil Mill & Fertilizer Co. has preliminary plans under consideration for the construction of a new plant on local site, estimated to cost approximately \$40,000.

Missouri

ST. LOUIS—The Day-Brite Reflector Co., 222 South 8th St., is arranging for the immediate establishment of a local plant for the manufacture of glass and other reflectors. A list of equipment to be installed has been prepared, including plating machines, buffing, polishing and kindred machinery, etc. O. W. Klingsick is president.

New Jersey

TRENTON—The Hamilton Rubber Mfg. Co., Mead St., manufacturer of automobile tires and mechanical rubber goods, has awarded a general contract to the Karno-Smith Co., Broad Street Bank Bldg., for the construction of a new 4-story addition to its plant, to cost about \$85,000. A 1-story structure will also be erected.

TRENTON—The Trenton Flint & Spar Co. has awarded a general contract to Bainford & Turner, Inc., Trenton, for the construction of a new 1-story addition at its plant on Marion St.

EDGEWATER—The Barrett Co., 40 Rector St., New York, manufacturer of prepared roofing, chemical products, etc., has preliminary plans under way for the construction of a 1-story building at its local plant, 50x100 ft.

HAZLET—The Fertilizer Supply Co. will commence the immediate construction of a new 1-story plant on local site, for the manufacture of a line of fertilizer products.

NEWARK—The Briggs Bituminous Composition Co., 17 Battery Place, New York, has acquired a local tract of land on Wilson Ave., 223x470 ft., for the construction of a new plant to occupy practically the entire site, for the manufacture of special chemical compounds and solutions for protection against corrosion. The initial plant is estimated to cost more than \$60,000, with equipment. The purchasing company also operates the Federal Paint Co., with plant at Brooklyn, N. Y. Andrew Baxter, Jr., is vice-president.

New York

BUFFALO—Kreiner & Lehr, 467 Spring St., operating a malt mill, have revised plans in preparation for the construction of a new 9-story addition, 35x80 ft., estimated to cost about \$100,000, including equipment. L. R. Veatch, Prudential Bldg., is architect and engineer.

NEW YORK—The National Gold Arsenic Corp., Room 2001, 25 West 42d St., is perfecting plans for the construction of the initial unit of its proposed new plant, on site to be selected in Georgia, for the production of calcium arsenate, to develop an initial output of about 25,000 tons per year. The works will cost in excess of \$300,000, with equipment.

TOTTENVILLE, S. I.—The Tottenville Copper Co. has filed plans for the construction of its proposed new 1-story plant on Bedell Ave., consisting of two buildings, 75x300 ft., and 35x75 ft., respectively, estimated to cost \$100,000, for which foundations will be laid at once.

Ohio

AKRON—The B. F. Goodrich Co., manufacturer of automobile tires and mechanical rubber goods, has purchased the tire-manufacturing business of the Brunswick-Balke-Collender Co., 629 South Wabash Ave., Chicago, Ill., with plant at Muskegon, Mich. The equipment now at the last noted location will be removed to the Akron works of the purchasing company, which will be extended to accommodate the expansion. The Brunswick Tire Corp. has been organized to operate this branch of the business.

Oklahoma

EDITH—The Santa Fe Salt Co. has acquired a tract of 2,000 acres of salt deposits in this vicinity, and plans for the early installation of a new plant for an initial output of approximately 500 tons per day. It will cost in excess of \$100,000, with equipment, and is expected to be ready for service early in the coming year.

Pennsylvania

GLASSMERE—The Alleghany Plate Glass Co. has commenced the construction of a new 2-story and basement addition to its plant, 105x124 ft., estimated to cost about \$100,000, for which a general contract was awarded recently to the Cuthbert Brothers Co., Bessemer Bldg., Pittsburgh.

PITTSBURGH—The United States Glass Co., Bingham and 9th Sts., has filed plans for the construction of a new building at its plant at 9th and Sarah Sts., to cost about \$25,000, for which foundations will be laid at once.

PHILADELPHIA—The Dodge Steel Works, Inc., State Road and Hellerman Sts., has construction under way on a new addition to its plant, to cost about \$25,000. Contract was awarded recently to the Austin Co., Bulletin Bldg.

LYKEN—The American Briquet Co., Land Title Bldg., Philadelphia, A. D. Parker, head, has awarded a general contract to the Shoemaker Bridge Co., 4 South 15th St., Philadelphia, for the construction of a new local plant for the manufacture of fuel briquets, to be 1- and 2-story, 60x220 ft., estimated to cost about \$350,000, with machinery.

Tennessee

CHATTANOOGA—The Dixie Consolidated Graphite Co., Birmingham, Ala., has acquired local property and plans for the construction of a new plant for the manufacture of finished commercial graphite product, with initial output of about 15,000 lb. per day, estimated to cost approximately \$260,000, including equipment. The company is operating with a capital of \$1,500,000. C. E. Watson is president.

NASHVILLE—The Western Electric Co., 195 Broadway, New York, is said to be negotiating for the purchase of a local tract of land, comprising about 15 acres, as a site for the construction of a new creosoting plant for wood pole treatment.

Virginia

MONETA—The Moneta Mineral & Mining Co. has plans under way for the erection of a new mill at its local feldspar properties, with installation to include crushing and classifying machinery, hoisting and conveying equipment and auxiliary apparatus. A power house will also be constructed.

CHINCOTEAGUE—The Assateague Fish Oil & Fertilizer Co., Inc., recently organized with a capital of \$500,000, has taken over the local plant of the Chincoteague Fish Oil & Guano Co., and purposes to develop maximum production. Two fertilizer plants of the last noted company at Lewes, Del., will also be operated.

West Virginia

CLARKSBURG—The American Sheet Glass Co. has commissioned the Simplex Engineering Co., Washington, Pa., to prepare plans for the proposed extensions and improvements in its local plant, formerly the works of the Liberty Glass Co., estimated to cost \$200,000. H. E. Travis is president.

Opportunities in the Foreign Trade

Parties interested in any of the following opportunities may obtain all available information from the Bureau of Foreign and Domestic Commerce at Washington or from any district office of the bureau. The number placed after the opportunity must be given for the purpose of identification.

INDUSTRIAL CHEMICALS, Barcelona, Spain, Purchase.—7615.

PAINTS, ENAMELS, VARNISHES, Rawalpindi, India. Purchase.—7619.

MANGANESE PEROXIDE, Rotterdam, Netherlands. Purchase and agency.—7614.

ROSIN, Aluminum sulphate, caustic soda, silicate of soda, chlorinated lime, soda ash, and sulphuric acid, Alexandria, Egypt. Purchase.—7640.

FATS AND OILS for soap making, Cologne, Germany. Purchase.—7628.

EDIBLE OILS AND LARD, Antofagasta, Chile. Agency.—7653.

PARAFFIN WAX, Antofagasta, Chile. Agency.—7654.

SCOURING SOAPS, in powder and cake form, Buenos Aires, Argentina. Agency.—7637.

New Companies

MUTUAL PAINT MFG. CO., St. Louis, Mo.; paints and varnishes; \$40,000. Incorporators: W. C. and J. J. Schmidt, both of St. Louis.

AMERICAN GASOLINE & REFINING CO., Los Angeles, Calif.; refined petroleum and by-products; \$1,000,000. Incorporators: E. P. Warner, Covina, Calif.; R. C. Davis, Pasadena, Calif.; and John H. Wents and George C. Wents, both of Anaheim, Calif.

DETROIT CINDER BLOCK & TILE CO., Detroit, Mich.; cement tile, blocks, etc.; \$250,500. Incorporators: Frederick Jones, W. S. Piggins and Frederic W. Dennis. 1830 Penobscot Bldg., Detroit.

LOVEJOY-SELBRO CHEMICAL CORP., Brooklyn, N. Y.; chemicals and chemical byproducts; \$25,000. Incorporators: L. J. and S. Seligman. Representative: A. A. Weinstein, 189 Montague St., Brooklyn.

PARA-FLUX RUBBER CO., Waltham, Mass.; rubber products; \$25,000. Patrick J. Dowd is president; and Louis J. Reynolds, Lexington, Mass., treasurer. The last noted is representative.

ARMOUR PRODUCTS CO., Chicago, Ill.; paints, varnishes, oils, etc.; \$1,000,000. Representative: United States Corporation Co., Dover, Del.

ITALY OIL MILL CO., Italy, Tex.; cottonseed oil products \$30,000. Incorporators: B. W. and J. C. Couch, and K. G. Stroud, all of Italy.

AUTOMOBILE GLASS MFG. CO., Brooklyn, N. Y.; automobile lenses and illuminating glassware; \$10,000. Incorporators: M. J. Schoen and P. E. Jacobs. Representative: W. Wayman, 55 Liberty St., New York.

HUBBARD FERTILIZER CO., Keyser Bldg., Baltimore, Md.; fertilizer products; \$10,000. Incorporators: Wilbur W. Hubbard and Wesley D. Wilson.

COMMONWEALTH PAPER CO., 1530 Newberry Ave., Chicago, Ill.; paper products; \$50,000. Incorporators: J. D. H. Murphy and A. B. Donlin.

WINGFIELD, DOBLE & WILSON, INC., Wilmington, Del.; refined oil products; \$500,000. Representative: Corporation Trust Co. of America, Du Pont Bldg., Wilmington.

HAYS BRASS & ALUMINUM FOUNDRY CO., Michigan City, Ind.; brass, aluminum, bronze and other metal castings; \$50,000. Incorporators: Philip T. Sprague, Joseph W. Hays and Robert B. Jones, all of Michigan City.

VENTOR CHEMICAL CO., 292 Webster Ave., Cranston, R. I.; chemicals and chemical byproducts; organized. Arthur Ventrone heads the company.

JAMES F. NUGENT OIL CO., Los Angeles, Calif.; refined petroleum products; \$350,000. Incorporators: Austin J. and James F. Nugent, Los Angeles; and Judson G. R. Smith, Long Beach, Calif.

EMPORIA COTTONSEED OIL CO., Emporia, Va.; cottonseed oil products; \$35,000. Incorporators: C. L. Vincent, Emporia; and J. E. Lipscomb, Greenville, S. C.

BLUEBOY PRODUCTS CORP., New York, N. Y.; chemicals and chemical byproducts; \$10,000. Incorporators: R. Maltz and I. Finkel. Representative: J. A. Whitehorn, 188 Montague St., Brooklyn, N. Y.

ALUMINUM FACTORIES, INC., 234 South Wells St., Chicago, Ill.; aluminum and kindred metals; \$100,000. Incorporators: Louis P. Mack, Moses and A. R. Levitan.

MAJOR PETROLEUM CO., New York, N. Y.; refined petroleum products; \$150,000. Representative: United States Corporation Co., 65 Cedar St., New York.

ARGO ASBESTOS & RUBBER CO., Pittsburgh, Pa.; asbestos and rubber products; \$25,000. Incorporators: L. A. Vezie, W. Carskaden and J. E. Alick, Pittsburgh. Representative: Capital Trust Co. of Delaware, Dover, Del.

COOLIDGE CHEMICAL CORP., New York, N. Y.; chemicals and chemical byproducts; \$10,000. Incorporators: M. J. Gallubier, C. Warner and A. Diamond. Representative: M. Monfried, 299 Broadway, New York.

LEAK-PROOF INNER TUBE CO., Newark, N. J.; tubes for automobile tires and other products; \$250,000. Incorporators: Edwin M. Skinner, Lloyd E. Harding and John A. Bernhardt, 763 Broad St., Newark. The last noted is representative.

PENNSYLVANIA BRASS & COPPER CO., Erie, Pa.; brass, copper, bronze and kindred products; \$50,000. E. S. Roach, Erie, is treasurer and representative.